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EFFECT OF ACETYLCHOLINE AND OF PHYSOSTIGMINE ON GASTRO-INTESTINAL MOTILITY

OBSERVATIONS OF NORMAL ANIMALS AND OF ANIMALS WITH EXPERIMENTAL PERITONITIS

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The extensive literature on the treatment of paralytic ileus and the constantly increasing number of methods for inducing intestinal motility indicate the lack of a satisfactory therapy for intestinal atonia. Recent attention has been directed toward acetylcholine and its probable function as the chemical mediator of parasympathetic nerve impulses. As such, it has been considered as an agent initiating gastro-intestinal motility, and attempts have been made to treat both experimental and clinical paralytic ileus with this preparation. It has been shown, however, that acetylcholine has an extremely evanescent action and that it is rapidly destroyed in the body by a specific ferment (esterase) which splits the ester into acetic acid and relatively inactive choline.

Physostigmine salicylate in extremely high dilutions has been found to inhibit the action of the esterase and greatly to augment and prolong the action of acetylcholine. These facts have not been applied clinically in the use of acetylcholine to stimulate gastro-intestinal motility, and without them, the evaluation of the effect of acetylcholine is difficult. For this reason, we have studied the action of acetylcholine and of physostigmine in stimulating gastro-intestinal motility in normal dogs and in animals in which the production of experimental paralytic ileus has been attempted.

REVIEW OF THE LITERATURE

Since Reid Hunt's [1] observations in 1906 of the vasodilator effects of choline esters, acetylcholine and its derivatives have received con-

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1. Hunt, R., and Taveau, R. de M.: Brit. M. J. **2**:1788, 1906.

siderable attention, notably from Hunt and his collaborators in this country and in the laboratory of Dale and his co-workers in England. These studies have tended to show that acetylcholine or its precursor is normally present in the body, that it is liberated whenever parasympathetic nerves are stimulated and that when injected, even in infinitesimal doses, it elicits parasympathetic effects. Dale and his group [2] (1914-1915) studied the stimulating effect of acetylcholine and of other choline esters on the motility of the gastro-intestinal tract. Guggenheim and Loeffler [3] (1916) were able to find choline in the blood of normal persons. Feldberg and Rosenfeld [4] (1933) found acetylcholine in the blood of the mesenteric veins, and Dale and Feldberg [5] (1934) found it in the perfusion fluid of the stomach. Magnus and Le Heux [6] (1918 to 1921) considered choline to be the hormone inducing intestinal motility, and Abderhalden and Pfaffrath [7] (1926) found that the intestine contains an esterase which is able to acetylize choline, thus producing a compound which is many times more potent than choline itself.

Attempts have been made to use choline and acetylcholine in the treatment of experimental paralytic ileus. Kühlewein,[8] in Magnus' laboratory (1921), reported that she paralyzed gastro-intestinal motility in cats by prolonged chloroform anesthesia and that she was able to reestablish peristaltic activity by the intravenous injection of from 5 to 15 mg. of choline per kilogram of body weight. Arai [9] (1922) produced peritonitis in anesthetized cats in several ways, including the injection of tincture of iodine and of bacterial emulsions into the peritoneal cavity. He observed that fluoroscopically, after a barium sulfate meal, increased peristalsis could be demonstrated after the injection of 10 mg. of choline hydrochloride per kilogram of body weight.

Carlson [10] (1927) injected choline into normal dogs and found increased tonus and peristalis in only a few of his experiments. Kahlson [11] (1933) found that the intestinal wall produces choline and that choline is necessary for the occurrence of peristalsis, although it does not produce it directly.

Choline and its compounds have been used therapeutically in clinical cases of ileus. Klee and Grossman [12] (1923) injected intravenously 600

2. Dale, H. H.: J. Pharmacol. & Exper. Therap. **6**:147, 1914-1915.
3. Guggenheim, M., and Loeffler, W.: Biochem. Ztschr. **74**:208, 1916.
4. Feldberg, W., and Rosenfeld, P.: Arch. f. d. ges. Physiol. **232**:212, 1933.
5. Dale, H. H., and Feldberg, W.: J. Physiol. **81**:320 (June 9) 1934.
6. Le Heux, J. W.: Arch. f. d. ges. Physiol. **173**:8, 1918; **179**:177, 1920; **190**:301, 1921.
7. Abderhalden, E., and Pfaffrath, H.: Fermentforsch. **8**:284 and 294, 1925.
8. Kühlewein, M.: Arch. f. d. ges. Physiol. **191**:99, 1921.
9. Arai, K.: Arch. f. exper. Path. u. Pharmakol. **94**:149, 1922.
10. Carlson, A. J.; Smith, E., and Sibbins, I.: Am. J. Physiol. **81**:435, 1927.
11. Kahlson, G.: Klin. Wchnschr. **12**:1015, 1933.
12. Klee and Grossman: München. med. Wchnschr. **18**:581, 1923.

mg. of choline prepared in Magnus' laboratory and reported favorable results. Spatz and Wichmann [13] (1924) used choline in twenty-one patients. They found that it stimulated motility in a few cases, frequently inhibited motility and had a toxic effect even in small doses. Wolff and Canney [14] (1926) reported good therapeutic results in three cases in which they slowly injected 600 mg. of choline intravenously. Abel [15] (1933) utilized acetylcholine as a prophylactic measure to prevent the development of postoperative ileus after abdominal operations. He injected 100 mg. of acetylcholine intravenously thirty-six hours after operation and repeated the dose every two or three hours. Usually two or three injections were sufficient to produce a bowel movement, and in none of a series of fifty abdominal operations did ileus develop. He considered acetylcholine a specific in postoperative ileus and recommended its use as a routine procedure.

Physostigmine salicylate has long been used in the treatment of postoperative ileus. Fröhner [16] stated in his textbook (1900) that physostigmine had been in common use in the treatment of ileus and of gastrointestinal atonia in animals. Cushny [17] reported good results from its use in the treatment of intestinal atony in man. Cannon and Murphy [18] (1907) stated that they produced ileus in anesthetized dogs by crushing the testes and were able to relieve it with physostigmine. Ochsner, Gage and Cutting [19] reported similar results, but their control experiments on normal dogs showed no increased motility after the administration of physostigmine.

Fuehner [20] (1918) found that the effects of acetylcholine in causing contractions of the back muscle of the leech were tremendously increased by the addition of physostigmine. Reid Hunt [21] (1917) described a similar fortification of the various effects of acetylcholine by physostigmine. He postulated the theory that this potentiation was due to the inhibition of an esterase which under normal conditions rapidly destroys acetylcholine. Matthes [22] (1930) and Loewi and Engelhart [23] (1930) sub-

13. Spatz, H., and Wichmann, E.: München. med. Wchnschr. **41**:1425, 1924.
14. Wolff, C. G. H., and Canney, J. R.: Lancet **1**:707, 1926.
15. Abel, A. L.: Lancet **2**:1247, 1933.
16. Fröhner, E.: Toxicologie für Tierärzte, Stuttgart, Ferdinand Enke, 1900.
17. Cushny, A. R.: A Text-Book of Pharmacology and Therapeutics or the Action of Drugs in Health and Disease, ed. 10, Philadelphia, Lea & Febiger, 1934.
18. Cannon, W. B., and Murphy, F. T.: Physiologic Observations on Experimentally Produced Ileus, J. A. M. A. **49**:840 (Sept. 7) 1907.
19. Ochsner, A.; Gage, I. M., and Cutting, R. A.: Value of Drugs in Relief of Ileus, Arch. Surg. **21**:924 (Dec., pt. 1) 1930.
20. Fuehner, H.: Arch. f. exper. Path. u. Pharmakol. **82**:51 and 205, 1918.
21. Hunt, R.: Am. J. Physiol. **45**:231, 1918.
22. Matthes, K.: J. Physiol. **70**:338, 1930.
23. Loewi, O., and Engelhart, E.: Arch. f. exper. Path. u. Pharmakol. **150**: 1, 1930.

sequently proved the correctness of this hypothesis and showed that this inhibition of the specific esterase was effective in dilutions of physostigmine as high as 1 : 40,000,000. With a small amount of physostigmine, acetylcholine can be demonstrated in the circulating blood. This inhibitory action is specific for eserine and is not possessed in comparable strength by any of the related alkaloids. The effect of physostigmine can be reversed by dialysis; so it may be assumed that the combination of physostigmine and esterase is a loose one. To our knowledge, the only clinical use of a combination of acetylcholine and physostigmine has been the work of Carmichael and Fraser [24] (1933), who administered both drugs intravenously to patients with diseases of the circulatory system but were not satisfied with the results.

There are several other choline esters which exhibit a similar pharmacologic effect but which are not hydrolyzed by the esterase. They are therefore more stable and apparently are preferable to the acetylcholine-physostigmine mixture for stimulating peristaltic activity. One such ester, acetyl-beta-methylcholine, was studied by Reid Hunt as early as 1911. This preparation has recently received considerable attention from Starr and his associates [25] (1933) and from Simonart [26] (1933) and is now available commercially. These investigators found acetyl-beta-methylcholine decidedly more effective than acetylcholine because of its greater stability. In experiments on dogs and cats, Comroe and Starr found that acetyl-beta-methylcholine increased peristalsis and tonus of the intestine. Starr and his co-workers injected from 5 to 15 mg. of acetyl-beta-methylcholine subcutaneously in normal human subjects and reported increased peristaltic activity of the entire gastrointestinal tract. This action was accompanied, however, by disagreeable side-effects, including salivation, flushing and abdominal pain. The oral administration of from 200 to 600 mg. yielded marked peristaltic effect without associated symptoms. Abbott [27] (1933) used acetyl-beta-methylcholine for patients with surgical ileus. Control tests on normal persons, with subcutaneous injection of from 5 to 20 mg. of acetyl-beta-methylcholine, produced increased tonus and peristalsis of the stomach, duodenum and colon.

From this review of the literature, it is seen that acetylcholine is the physiologic stimulant of peristaltic activity, that it is quickly destroyed by the blood and tissues and that its destruction is prevented

24. Carmichael, E. A., and Fraser, A. R.: Heart **16**:263, 1933.

25. Comroe, J. H., and Starr, I.: J. Pharmacol. & Exper. Therap. **49**:283, 1933.

26. Simonart, A.: J. Pharmacol. & Exper. Therap. **46**:157, 1932.

27. Abbott, W. O.: Am. J. M. Sc. **186**:323, 1933.

for a relatively long period by minute concentrations of physostigmine. Physostigmine furthermore intensifies the action of acetylcholine, permitting a striking reduction in the effective dosage of the latter drug. Other choline esters, notably the acetyl-beta-methylcholine, possess a similar action but are much more stable, and hence more effective, than acetylcholine. For these reasons it seemed reasonable to study the effect of acetylcholine in combination with physostigmine in combating intestinal atonia and to compare its action with that of acetyl-beta-methylcholine.

EXPERIMENTAL METHODS

The experiments were conducted on dogs under light ether anesthesia. Blood pressure was registered by means of a cannula in the carotid artery, in the usual way. Rubber balloons were introduced into the stomach, small intestine and colon and connected with water manometers, and the abdominal wound was closed. The body temperature was maintained by a heated operating table. Slow, constant intravenous infusions of 1 per cent of dextrose in a physiologic solution of sodium chloride were given throughout the course of the experiments, at the rate of about 35 cc. per hour, by means of a constant injection pump. Studies of gastro-intestinal motility were made in normal animals and in dogs in which the development of paralytic ileus was attempted by the production of peritonitis and by other measures which are supposed to result in intestinal paralysis. The results of these efforts will be described below.

TABLE 1.—*Types of Motility*

Excursion of Manometer, Cm.	Type of Motility
0	0
0 to 1	1
1 to 5	2
5 to 10	3
Above 10	4

The drugs used were acetylcholine, physostigmine salicylate and acetyl-beta-methylcholine.[27a] The injections were given intramuscularly or intravenously. Before each injection, the motility of the intestine was recorded for from one half to one hour as a control period. Injections were given when tonus and peristalsis were regular and minimal. The motility in these experiments is expressed in four grades, according to the height of excursion of the water manometer (table 1).

Experiments in Normal Animals.—A. Physostigmine, Acetylcholine and Physostigmine and Acetylcholine: A preliminary report of these experiments has been made.[28] Physostigmine salicylate was used alone, by intramuscular injection, in doses of from 0.5 to 3 mg. It was found that quantities less than 1 mg. usually produced no recognizable effect on gastro-intestinal motility. Doses above 1.5 mg.

27a. Hoffmann-La Roche supplied the acetylcholine and Merck & Co. supplied the acetyl-beta-methylcholine used in this work.

28. Frank, R.; Zimmerman, L. M., and Necheles, H.: Proc. Soc. Exper. Biol. & Med. **32**:686, 1935.

often caused undesirable concomitant effects, such as excessive salivation, increased respiration and a tetanic contraction of the intestine. One milligram of physostigmine salicylate did not cause these undesirable effects, but a demonstrable increase in gastro-intestinal peristalsis was seen in only 50 per cent of the experiments.

The intramuscular injection of 0.025 mg. of acetylcholine alone had no demonstrable effect on blood pressure or on intestinal motility. When this quantity of acetylcholine was combined with 1 mg. of physostigmine salicylate, a slight drop in blood pressure, of from 10 to 15 mm. of mercury, occurred, which disappeared after from 2 to 3 minutes. As will be seen in table 2, this combination produced peristalsis in the stomach, small intestine and colon in almost all the animals.

TABLE 2.—*Effect of Intramuscular Injection of Physostigmine (1 mg.) and of Physostigmine (1 mg.) Plus Acetylcholine (0.025 mg.) on Gastro-Intestinal Motility*

	Stomach		Ileum		Colon	
	Physostigmine	Physostigmine plus Acetylcholine	Physostigmine	Physostigmine plus Acetylcholine	Physostigmine	Physostigmine plus Acetylcholine
Increased peristalsis.....	8	12	6	11	10	13
No effect.....	8	2	10	3	6	1

B. Acetyl-Beta-Methylcholine: A dose of 0.1 mg. of acetyl-beta-methylcholine given intramuscularly caused a drop of blood pressure of from 20 to 60 mm. Most of the dogs did not recover from this injection and died of circulatory failure, but there was no effect on gastro-intestinal motility. Rectal injection of 600 mg. of acetyl-beta-methylcholine was ineffective. Oral administration was not tried because this route would probably not be available in cases of paralytic ileus.

Experiments in Animals with Paralytic Ileus.—Attempts were made to produce a state of paralytic ileus in dogs comparable to that which occurs in man and to determine the effect of the acetylcholine-physostigmine mixture on gastro-intestinal motility under those conditions. The following measures were tried:

A. Induction of peritonitis with croton oil. A mixture of croton oil in olive oil was injected into the peritoneal cavity. Ten cubic centimeters of the mixture contained 1 drop of croton oil, and, according to the size of the animal, from 10 to 15 cc. of this mixture was injected. Peritonitis developed rapidly. In from one to three hours the abdominal cavity contained from 100 to 200 cc. of hemorrhagic fluid, and the serous surfaces of the gastro-intestinal tract were markedly injected and covered with a fibrinous exudate. The peritonitis was so severe that if the croton oil mixture was injected the night before the experiment the animal often died before morning or was so sick that it did not survive the anesthesia and the preliminary steps of the experiments.

B. Induction of peritonitis with aqueous solution of iodine U. S. P. Twenty-four hours before the experiment, from 7 to 25 cc. of compound solution of iodine U. S. P. (Lugol's solution) was injected intraperitoneally, and immediately before

the experiment from 10 to 30 cc. was given, depending on the intensity of the peritonitis present and the degree of intestinal atonia.

C. Induction of peritonitis with iodine. From 10 to 50 cc. of 5 per cent tincture of iodine was injected intraperitoneally before the experiment.

D. Induction of peritonitis with bile. From 10 to 30 cc. of dog's bile was injected intraperitoneally before the experiment.

E. Induction of peritonitis with the colon bacillus. Injection of washings of cultures of Bacillus coli was made intraperitoneally before the experiment.

F. Induction of peritonitis with feces. Injection of an emulsion of dog's feces was made intraperitoneally, twenty-four hours before the experiment.

G. Trauma to the gastro-intestinal tract, crushing of the testes, high aseptic ligation of the jejunum twenty-four hours before the experiment and prolonged chloroform anesthesia.

We were unable to produce a complete and generalized paralytic ileus comparable to that which is seen in human beings. In spite of the long list of methods enumerated, all of which have been reported by others to result in intestinal paralysis, we succeeded in causing at best only a relative paresis. This relative ileus consisted of prolonged periods of quiescence and atony of the gastro-intestinal tract, which were followed by phases of more or less vigorous contraction. These extended intervals of quiescence and atony were used in our experimental efforts to stimulate motility and tonus. Complete atony of the gastro-intestinal tract was often observed in the terminal stages of peritonitis, when the blood pressure had fallen and the dog was moribund. Animals in this condition could not be used for testing effects of the drugs.

Since we found croton oil to be the most uniformly effective and reliable agent in producing peritonitis and with it a relative paralytic ileus, we are presenting only those experiments in which this substance was used. Ten experiments were done on nine dogs. All injections were given intramuscularly. As in the previous series, physostigmine and acetylcholine were first tried alone and then the two drugs in combination. No gastro-intestinal motility could be induced by small doses of acetylcholine alone (from 0.01 to 0.02 mg.), and only inconstant effects were produced by small doses of physostigmine (up to 1 mg.). These results are similar to those found by us [28] in normal animals.[29] The response to 0.02 mg. of acetylcholine and 1 mg. of physostigmine injected together in the dogs with peritonitis was greater than that to 0.025 mg. of acetylcholine and 1 mg. of physostigmine in the normal animals. The latent period was somewhat shorter than that in normal animals. There was no significant drop in blood pressure or change

29. Ellis and Weiss reported that man is more resistant to acetylcholine than are animals (J. Pharmacol. & Exper. Therap. **44**:235, 1932).

TABLE 3.—*Effect of Acetylcholine and Physostigmine on Gastro-Intestinal Motility in Peritonitis*

Experiment	Dose, Mg.		Latent Period in Minutes			Increased Motility						Blood Pressure After Injection	Comment
						Stomach		Small Intestine		Colon			
	Acetylcholine	Physostigmine	Stomach	Small Intestine	Colon	Minutes	Type	Minutes	Type	Minutes	Type		
1	0.02	1	20	15	8	30 10 10	Increased tone 0 Increased tone	20	1	60	2 to 3 2-	No change	
2	0.01	1	15	10	5	2	4	40	4 to 3	110	4 to 3	No change	
3	0.02	1	5	10	1	60	Increased tone	80	2 to 4	60	2 to 3	No change	
4	0.01	2	5	5	5	75	2 to 4 and increased tone	75	2 to 3 and increased tone	75	2 to 3 and increased tone	No change	
5a	0.01	2	5	5	..	35	2 to 3 and increased tone	80	2 to 3 and increased tone	..	..	No change	
5b	0.01	3	10	3	..	30	3 to 4	25	2 to 3	..	..	No change	Panting after injection
6	0.01	3	2	2	2	60	2 to 3 and increased tone	60	1 to 2	60	2 and increased tone	Drop; death after 60 minutes	
7	0.01	3	5	3	4	55	Increased tone	50	Increased tone	50	3 to 4 and increased tone	No change	
8	0.01	3	5	5	5	25	Increased tone	30	3 and increased tone	15	1 to 2	No change	Panting after injection
9	0.01	3	12	5	5	15	1 to 2 and increased tone	40	4	30	3 to 4	No change	

in respiration following the injection of the combination of drugs with doses of physostigmine of from 1 to 2 mg. Owing to the severity of the peritonitis and the prolonged duration of the experiments, there was, however, a slow and gradual decline in blood pressure.

COMMENT

In these experiments we attempted to stimulate gastro-intestinal motility by means of acetylcholine, which is apparently the physiologic agent of peristaltic activity of the digestive tract. In order to obtain the full effect of this mechanism it was necessary to give it in combination with physostigmine, which inhibits the rapid destruction of acetylcholine in the fluids and tissues of the body. In normal animals, we found that small doses of physostigmine alone, in quantities up to 1 mg., had no effect on blood pressure or other bodily functions, as far as we were able to ascertain, and only inconstant effect on gastro-intestinal motility. Small doses of acetylcholine, which alone were incapable of stimulating gastro-intestinal motility did produce peristaltic activity when combined with physostigmine, and caused little or no change in blood pressure. In dogs with peritonitis, physostigmine in doses of 1 mg. combined with from 0.01 to 0.02 mg. of acetylcholine produced a greater degree of gastro-intestinal motility than they did in the normal animals. Increasing the quantity of physostigmine, with the smaller doses of acetylcholine, did not appreciably increase the peristaltic effect (table 2, experiments 1 to 3 and 4 to 9).

The effectiveness of the acetylcholine-physostigmine mixture in the animals with peritonitis suggests its clinical use in cases of paralytic ileus. Acetyl-beta-methylcholine was discontinued in our studies because when injected it apparently had more pronounced effects on the cardiovascular system than on the gastro-intestinal tract. Starr and Comroe stated that the cardiovascular effects of acetyl-beta-methylcholine are mild or absent after oral administration, but as we were seeking an agent to use in conditions with paralytic ileus which might preclude the oral route, a substance which could be injected was necessary. In one experiment, relatively large doses of acetyl-beta-methylcholine were not effective when given by rectum.

SUMMARY

Acetylcholine, physostigmine and a combination of acetylcholine and phystostigmine were tested as to their effect on the production of gastro-intestinal motility in normal dogs and in animals with experimental peritonitis.

Small doses of acetylcholine alone had very little or no effect on peristaltic activity in either group.

Small doses of physostigmine alone had inconstant effects on gastro-intestinal motility.

Intramuscular injection of small doses of physostigmine in combination with acetylcholine always produced increased gastro-intestinal motility, without significant cardiovascular disturbances or other undesirable manifestations.

Animals with peritonitis responded somewhat more to the acetylcholine-physostigmine mixture than did the normal ones.

Attempts were made to produce complete paralytic ileus by a number of different procedures. None were successful, except in the terminal stages, when the dogs were no longer in condition for experimentation. A relative ileus resulted from chemical peritonitis, which was characterized by prolonged periods of atony and quiescence. These atonic intervals were used in studying the effects of physostigmine and acetylcholine on gastro-intestinal motility in the presence of peritonitis.

ALLERGY AS AN EXPLANATION OF DEHISCENCE OF A WOUND AND INCISIONAL HERNIA

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Dehiscence or disruption of a wound occurs with sufficient frequency to warrant the presentation of a symposium on this subject before the New York Surgical Society in 1933. Papers were read by members of the staffs of five hospitals in New York, and Meleney and Howes [1] reported 55 cases from the Presbyterian Hospital in an eight year period, or an incidence of 1 per cent. They thought that the diagnosis had been frequently omitted from the records if there had not been a secondary closure and that 2 per cent would more nearly represent the incidence of this catastrophe. Colp [2] reported 29 cases in 2,750 laparotomies, or an incidence of 0.9 per cent, from the Mount Sinai Hospital. Grace [3] reported 44 cases in a fifteen year period from the first surgical division of the Bellevue Hospital. White [4] reported 30 cases from the Roosevelt Hospital. Heyd [5] reported 4 cases in 1,000 laparotomies performed at the New York Post-Graduate Hospital in 1932 and 4 personal cases. There was a total of 166 cases reported at the meeting of the New York Surgical Society. Sokoloff [6] in 1931 reported the largest group of cases on record, numbering 725, based on the experience of 187 surgeons. He sent questionnaires to 1,140 European surgeons. Eliason and McLaughlin [7] reviewed 9,155 operations at the University of Pennsylvania Hospital and found 25 instances of dehiscence. Maes,

1. Meleney, Frank L., and Howes, Edward L.: The Disruption of Abdominal Wounds with the Protrusion of the Viscera, Ann. Surg. **99**:5 (Jan.) 1934.

2. Colp, Ralph: Disruption of Abdominal Wounds, Ann. Surg. **99**:14 (Jan.) 1934.

3. Grace, Roderick V.: Disruption of Abdominal Wounds, Ann. Surg. **99**: 28 (Jan.) 1934.

4. White, William C.: Disruption of Abdominal Wounds, Ann. Surg. **99**: 34 (Jan.) 1934.

5. Heyd, Charles G.: Disruption of Abdominal Wounds, Ann. Surg. **99**:39 (Jan.) 1934.

6. Sokoloff, S.: Die postoperative Ruptur der Bauchwunde mit Hervortreten oder Vorfall der Eingeweide, Vestnik khir. (nos. 65-66) **22**:219, 1931.

7. Eliason, E. L., and McLaughlin, Charles: Post-Operative Wound Complications, Ann. Surg. **100**:1159 (Dec.) 1934.

Boyce and McFetridge [8] reported 44 cases in a ten year period at the Charity Hospital in New Orleans. Baldwin [9] reviewed his individual series and found that in the past thirty-five years he has not had a single instance of dehiscence in 16,465 operations. After one studies these reports as to the cause, prevention and treatment of this serious sequela of celiotomy, it is difficult to evaluate the opinions expressed by the different authors.

The foregoing reports convince one that the type of incision, the magnitude of the operation, the choice of the anesthetic or the type of closure plays only an insignificant part in dehiscence of the wound. Colp [2] summarized the subject by stating that the anesthetic, the type of wound closure and infection or drainage of the wound have little or no relation to the frequency of dehiscence. Meleney and Howes [1] stressed the importance of infection of the wound in cases of dehiscence but said that chromic catgut is completely absorbed in "clean cases" in which bacterial cultures are negative and whether the wound disrupts on the third or on the thirteenth postoperative day. There is a warning note by all authors as to the peculiar capacity of the tissues of some persons to digest catgut completely. Erdmann [10] referred to tissue hunger, which digests the gut too early. Colp [2] spoke of idiosyncrasy of the patient as a possible factor. White [4] referred to a predisposing factor for which a name cannot be given, and stated that the body tissue causes an early dissolution of the catgut in the absence of infection of the wound. Sokoloff [6] stressed the fact that in only 15.7 per cent of 725 cases was the wound infected. He was so amazed at the low incidence of infection that these cases were carefully rechecked to verify this point. Maes, Boyce and McFetridge [8] stressed infections of the respiratory tract as a cause, but this is not borne out in other reports. Other factors that have been stressed by different authors, such as distention, vomiting and chronic debilitating diseases with secondary anemia, are not borne out as real factors when one carefully analyzes a large series of cases.

A review of the reports of the different authors reveals that they have not stressed the fact that dehiscence of the wound in all probability is a more advanced stage of the same process that produces incisional hernia and causes inguinal hernia to recur after the many different methods of repair that have been advocated.

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8. Maes, Urban; Boyce, Frederick, and McFetridge, Elizabeth: Post-Operative Evisceration, Ann. Surg. **100**:968 (Nov.) 1934.

9. Baldwin, J. F.: Disruption of Abdominal Wounds, Am. J. Surg. **25**:7 (July) 1934.

10. Erdmann, John F.: The Recognition and Treatment of Post-Operative Complications, South. Surgeon **11**:193 (Sept.) 1933.

To have a clear conception of the complete picture of dehiscence of the wound it would seem justifiable to divide it into three stages. Stage 1 consists of complete separation of the peritoneum and the posterior sheath of the rectus abdominis muscle with incomplete separation of the anterior sheath of the rectus abdominis muscle. In such cases the wound heals by primary union, with the exception of a slight serosanguineous discharge on from the fifth to the eighth day. The discharge is usually attributed to a hematoma, but if the wound is not tightly strapped to reenforce the entire abdominal layers, an incisional hernia is most likely to occur. A follow-up study of cases of this type reveals a high incidence of incisional hernia after from six to twelve months. Stage 2 consists of complete separation of the entire abdominal layers without protrusion of an abdominal viscus. Stage 3 consists of complete separation of the abdominal layers with protrusion of an abdominal viscus.

It would seem that an analysis of 19 cases occurring in the experience of one person might help to throw some light on many of the points under discussion in regard to dehiscence of a wound. For that reason a résumé of 19 instances of dehiscence occurring in 621 laparotomies in the past thirteen years, or an incidence of 3.05 per cent, will be presented.

REPORT OF CASES

CASE 1.—A man aged 40 was admitted to the New York Post-Graduate Medical School and Hospital in November 1923, for cholecystitis and cholelithiasis. A cholecystectomy and appendectomy were performed with the patient under ether anesthesia. A cigaret drain was inserted to the gallbladder fossa. The peritoneum was closed with a continuous suture of no. 2 plain catgut, and the fascia, with a continuous suture of no. 2 chromic catgut. Four retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the fifth postoperative day there was a moderate amount of serosanguineous discharge, which completely saturated the dressing and necessitated the dressing of the wound twice daily for the next three days, after which there was a moderate amount of discharge for three more days. The patient left the hospital on the twentieth day. The dehiscence was of the stage 1 type.

Bronchitis of moderate severity developed, with only a slight cough. With the exception of the serosanguineous discharge and cough, the patient's convalescence was uninterrupted. A small incisional hernia was noticed six months after he left the hospital, and it gradually enlarged in spite of the fact that he wore an abdominal belt. In February 1930 he was readmitted to the hospital and operated on for the hernia, a Gallie fascial repair being done. He has been cured since this operation.

CASE 2.—A man aged 43 was admitted to the Bellevue Hospital in October 1924, with a perforated duodenal ulcer. A Horsley pyloroplasty was performed

with the patient under ether anesthesia. The peritoneum was closed without drainage with a continuous suture of no. 2 plain catgut, and the fascia was closed with a continuous suture of no. 2 chromic catgut. Three retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the sixth postoperative day there was a serosanguineous discharge on the dressing, and on the seventh day the wound had partly separated, with the small intestine protruding. The patient was taken to the operating room, and the wound was closed as before. Firm union resulted in fourteen days. The dehiscence was of the stage 3 type.

The postoperative course in this case was uneventful. The patient did not suffer from distention and did not vomit, and there were no pulmonary complications. The wound was not infected, and primary union resulted after the second closure. The patient was readmitted to the hospital in 1927 with acute appendicitis. He was operated on by me, and the original scar was firm at that time.

Case 3.—A man aged 48 was admitted to the Bellevue Hospital in June 1925 with a perforated duodenal ulcer. A Horsley pyloroplasty was performed with the patient under ether anesthesia. The peritoneum was closed without drainage with a continuous suture of no. 2 plain catgut, and the fascia was closed with a continuous suture of no. 2 chromic catgut. Three retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the seventh postoperative day the dressing was saturated with a serous discharge, and when the wound was inspected and the silk sutures removed, the small intestine was found lying beneath the skin. The patient was immediately reoperated on, and the wound was closed as formerly. The wound became infected but healed in thirty days after the second closure. The dehiscence was of the stage 2 type.

The patient's convalescence was uninterrupted up to the time of dehiscence of the wound. There was no evidence of infection at the time of the second closure, but in spite of a severe infection an incisional hernia did not occur. Pyloric stenosis developed, and gastro-enterostomy was performed in September 1927. The patient has been followed in the "stomach clinic" of the fourth surgical division since, and the wounds are firm at the time of writing.

Case 4.—A woman aged 45 was admitted to the Bellevue Hospital in October 1927, with acute cholecystitis and cholelithiasis. A cholecystectomy was done with the patient under ether anesthesia. A cigaret drain was inserted to the gallbladder fossa. The peritoneum was closed with a continuous suture of no. 2 plain catgut, and the fascia with a continuous suture of no. 2 chromic catgut. Three retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the fifth postoperative day there was a serosanguineous discharge, which persisted until the seventh day, and then the edges of the skin were partly separated. On removing the silk suture, the wound was found to be completely separated, but no viscus was protruding. The wound was closed as originally. A slight infection resulted, but the wound was healed in twenty days following the second operation. The dehiscence was of the stage 2 type.

There was a slight cough for four days, but the convalescence was otherwise uninterrupted. The wound was clean at the time of dehiscence. The patient left the hospital twenty days after the second closure, and the wound was firm. She has not been followed.

CASE 5.—A man aged 35 was admitted to the New York Post-Graduate Medical School and Hospital in January 1928, with acute cholecystitis, cholelithiasis and acute appendicitis. A cholecystectomy and an appendectomy were done with the patient under ether anesthesia. A cigaret drain was inserted to the gallbladder fossa. The peritoneum was closed with a continuous suture of no. 2 plain catgut, and the fascia with a continuous suture of no. 2 chromic catgut. Four retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the sixth postoperative day there was a moderate serosanguineous discharge. The wound was strapped with adhesive tape, and the sutures were not removed from the skin as the patient was an apprehensive lawyer. The wound apparently healed by primary union, and the patient left the hospital on the twentieth postoperative day. A small incisional hernia soon developed. At the time this paper is written the patient has a large hernia which needs to be repaired. The dehiscence was of the stage 1 type.

I feel that if the sutures had been removed at the time the discharge was noted the wound would have separated. If an immediate repair had been done a hernia might possibly have been prevented.

CASE 6.—A woman aged 33 was admitted to the Bellevue Hospital in April 1928, for cholecystitis and cholelithiasis. She was operated on under spinal anesthesia and found to have a large echinococcus cyst of the liver, located between the gallbladder and the surface of the liver and partly embedded in the substance of the liver. The cyst was completely enucleated, and a cholecystectomy was done. The abdomen was drained with iodoform gauze. The peritoneum was closed with a continuous suture of no. 2 plain catgut, and the fascia, with a continuous suture of no. 2 chromic catgut and five interrupted sutures of chromic catgut. Five retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

The postoperative course was marked by pleurisy on the right side with effusion, which necessitated two aspirations. The patient was critically ill for several days. There was complete dehiscence of the wound on the eighth day. The patient was very ill, so the wound was merely strapped and was dressed several times a day. It healed on the forty-fifth day, and the patient was discharged without a hernia. There was a moderate infection of the wound. The dehiscence was of the stage 2 type.

The patient has been seen on numerous occasions since leaving the hospital, and there is no evidence of a hernia.

CASE 7.—A man aged 39 was admitted to the Bellevue Hospital in August 1929. He was referred from the "stomach clinic" with a chronic duodenal ulcer. The ulcer was excised and a gastro-enterostomy was performed, spinal anesthesia being used. The peritoneum was closed with a continuous suture of no. 2 plain catgut, and the fascia, with a continuous suture of no. 2 chromic catgut. Three retention

sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the sixth postoperative day the wound was saturated with a serosanguineous discharge, and on removing the sutures from the skin the wound was found to be completely separated, but no viscus protruded on the abdomen. The wound was closed as originally. A moderate degree of infection developed after the second closure, but the wound completely healed in twenty-four days. The dehiscence was of the stage 2 type.

There were no complications in this case during convalescence to account for the dehiscence of the wound. The patient has been followed in the "stomach clinic," and the wound is firm at the time of writing.

Case 8.—A man aged 42 was admitted to the Bellevue Hospital in August 1929. He was referred from the "stomach clinic" with a chronic duodenal ulcer with recurring hemorrhages. The ulcer was excised, and a gastro-enterostomy was performed with the patient under spinal anesthesia. As the patient in case 7 had been operated on one week before, it was decided to use a different make of catgut. The peritoneum was closed with a continuous suture of no. 2 plain catgut to which were added five interrupted sutures of plain catgut. The fascia was closed with a suture of continuous no. 2 chromic catgut and also reenforced with interrupted sutures of chromic catgut. Three retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the seventh postoperative day the dressing was saturated with a serous discharge. When the silk sutures were removed, the omentum protruded on the abdomen. The patient was operated on under spinal anesthesia, and the wound was closed with through-and-through sutures of silkworm gut. The wound healed on the fourteenth day without infection. The dehiscence was of the stage 3 type.

The patient had a definite bronchitis but not true pneumonia. Since his discharge he has been followed in the clinic, and his wound has remained firm.

Case 9.—A woman aged 53 was admitted to the Bellevue Hospital in August 1929, with cholecystitis and cholelithiasis. Cholecystectomy was performed with the patient under spinal anesthesia. A cigaret drain was inserted to the gallbladder fossa. As the patient was operated on the same day that the wound of the patient in case 8 was resutured, I was more than concerned about the closure. Still a different make of catgut was used, and the peritoneum was closed with interrupted sutures of no. 2 plain catgut. The sutures were placed ¼ inch (0.6 cm.) apart. The fascia was closed in a like manner with no. 2 chromic catgut. Four retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

On the eighth postoperative day there was a serosanguineous discharge, and when the sutures were removed from the skin the wound was found to be completely separated. The wound was resutured with through-and-through sutures, spinal anesthesia being used. Healing occurred in twenty days with a slight infection. The dehiscence was of the stage 3 type.

There were no postoperative complications in this case and no evidence of infection at the time of the dehiscence. The wound was firm on the day of discharge, twenty days after the second closure.

CASE 10.—A man aged 37 was admitted to the Bellevue Hospital in September 1930, with a chronic duodenal ulcer. A posterior gastro-enterostomy and an appendectomy were done with the patient under spinal anesthesia.

The convalescence was uninterrupted, and the patient was out of bed on the thirteenth postoperative day, with apparently primary union of the wound. That night he complained of a sensation of warmth and of something giving away. When the wound was dressed, complete separation was found, with the small intestine protruding on the abdomen. He was operated on under spinal anesthesia, and the intestine was replaced. The wound was closed with through-and-through sutures of silkworm gut. The wound healed without any evidence of infection, and the patient was discharged from the hospital eighteen days later. The dehiscence was of the stage 3 type.

The patient's convalescence both before and after the first and second operations was uninterrupted, and there was no evidence of infection of the wound.

CASE 11.—A man aged 34 was admitted to the New York Post-Graduate Medical School and Hospital in February 1931, because of a chronic duodenal ulcer. The ulcer was excised and a posterior gastro-enterostomy and appendectomy were done with the patient under ether anesthesia. The peritoneum was closed with a continuous suture of no. 2 plain catgut and reenforced with three interrupted sutures. The fascia was closed with a continuous suture of no. 2 chromic catgut and reenforced with interrupted sutures. Three retention sutures of silkworm gut were used for the fascia, and the skin was closed with a silk suture.

The patient had an uninterrupted convalescence until the seventh day, when the dressing was saturated with a serosanguineous discharge. This necessitated the dressing of the wound twice a day for the next three days and once daily for four more days. With the exception of the discharge, the wound apparently healed by primary union, and the patient left the hospital on the eighteenth day. When he was reexamined three months after leaving the hospital there was evidence of a small incisional hernia. He has worn an abdominal belt, and the hernia has gradually enlarged. At the time of writing he has a large incisional hernia which should be operated on. There was no infection of the wound in this case, and no complications to account for the dehiscence, which was one of the stage 1 type.

CASE 12.—A man aged 37 was admitted to the Park West Hospital in May 1932 for a carcinoma of the stomach. Resection of the stomach and an anticolic Polya anastomosis was done with the patient under ether anesthesia. The peritoneum was closed with a continuous suture of no. 2 plain catgut and reenforced with interrupted sutures. The fascia was closed with a continuous suture of no. 2 chromic catgut and reenforced with interrupted sutures. Three retention sutures of silkworm gut were used, and the skin was closed with a silk suture.

The patient's convalescence was uninterrupted until there was a serosanguineous discharge on the eighth day with a complete separation of the wound. The wound was resutured with through-and-through sutures, ether anesthesia being used. The patient made an uninterrupted convalescence and was discharged from the hospital sixteen days later. The dehiscence was of the stage 2 type.

There was no evidence of pulmonary complications or of infection of the wound to account for the dehiscence. The patient has been followed since leaving the hospital, and he is well, without any evidence of incisional hernia.

CASE 13.—A man aged 38 was admitted to the Bellevue Hospital in January 1932, with a duodenal ulcer which had perforated into the liver and had necessitated an operation six months previously. Operation was performed with the patient under ether anesthesia, and he was found to have a large duodenal ulcer which had perforated into the liver and was difficult to free. Subtotal resection of the stomach and an anticolic Polya anastomosis were done. The peritoneum was closed with a continuous suture of no. 2 plain catgut and reenforced with four interrupted sutures of no. 2 plain catgut. The fascia was closed with a continuous suture of no. 2 chromic catgut and reenforced with four interrupted sutures of chromic catgut. Four retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

The patient was critically ill after the operation. He had definite evidence of peritonitis on the second postoperative day. On the fifth day the wound was infected and completely separated. The patient was acutely ill from extensive peritonitis at this time. The wound was strapped with adhesive tape, but the patient died on the seventh postoperative day as a result of generalized peritonitis. The dehiscence was one of the stage 2 type.

Death in this case was due to peritonitis, and the dehiscence of the wound did not cause the fatality.

CASE 14.—A woman aged 48 was admitted to the Bellevue Hospital in October 1933, with a chronic duodenal ulcer. Operation was performed with the patient under ether anesthesia and a chronic duodenal ulcer was found as well as a large mesenteric cyst near the ligament of Treitz, which was adherent to the transverse colon. The operation consisted in complete enucleation of the cyst, which was the size of a large grapefruit, but during the procedure the blood supply of the transverse colon was damaged, and it was necessary to make a lateral anastomosis between the ascending and the descending colon. The peritoneum was closed with a continuous suture of no. 2 plain catgut and reenforced with four interrupted sutures of plain catgut. The fascia was closed with a continuous suture of no. 2 chromic catgut and reenforced with four interrupted sutures. Three retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

The patient had a moderate amount of abdominal distention, but otherwise her convalescence was uninterrupted until the sixth postoperative day, when there was a serosanguineous discharge. The sutures were removed from the skin, and the wound beneath the skin was found to be completely separated. The wound was resutured with through-and-through sutures of silkworm gut, ether anesthesia being used. The patient's convalescence was uninterrupted, and she left the hospital on the eighteenth postoperative day. The dehiscence was of the stage 2 type.

The patient's wound was not infected at the time of the dehiscence, but a slight infection resulted after the second closure. She was followed in the "stomach clinic" of the Bellevue Hospital for a few months but failed to return. In March 1935 she was readmitted to the hospital with a tremendous incisional hernia.

CASE 15.—A woman aged 43 was admitted to the Murray Hill Sanatorium in February 1933, with a diagnosis of duodenal obstruction. Operation with the patient under ether anesthesia revealed the stomach to be markedly dilated from a chronic duodenal obstruction, and a gastro-enterostomy was performed. The

peritoneum was closed with a continuous suture of no. 2 plain catgut but was not reenforced with interrupted sutures. The fascia was closed with a continuous suture of no. 2 chromic catgut, but was not reenforced with sutures of chromic catgut. Retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with a silk suture.

This patient's convalescence was uninterrupted until the sixth postoperative day, when there was profuse serosanguineous discharge. The sutures were not removed from the skin, but the wound was strapped. The wound healed by primary union, with the exception of the discharge. The patient left the hospital on the seventeenth postoperative day. The dehiscence was of the stage 1 type.

The patient has been followed by her attending physician, and an incisional hernia was noticed within three months of the time of her discharge from the hospital.

CASE 16.—A man aged 32 was admitted to the New York Post-Graduate Medical School and Hospital in July 1934, with a chronic duodenal ulcer. Subtotal resection of the stomach and an anticolic Polya anastomosis were done with the patient under ether anesthesia. The peritoneum was closed with a continuous suture of no. 2 plain catgut and reenforced with interrupted sutures of plain catgut. The fascia was closed with a continuous suture of no. 2 chromic catgut and reenforced with four interrupted sutures of chromic catgut. Four retention sutures of silkworm gut were used beneath the fascia, and the skin was closed with silk sutures.

The patient's convalescence was uninterrupted until the seventh postoperative day, when the wound was dressed and found to be clean. On the afternoon of the same day there was a profuse serosanguineous discharge, and when the sutures were removed from the skin the wound was found to be completely separated, and the intestine protruded on the abdomen. The patient was reoperated on under spinal anesthesia, and the abdomen was closed with through-and-through retention sutures of silkworm gut. A slight infection of the wound developed after the second closure, but the patient left the hospital sixteen days after the second operation. The dehiscence was of the stage 3 type.

The patient has been followed regularly since she left the hospital, and the wound is firm at the time this report is written.

CASE 17.—A woman aged 53 was admitted to the Bellevue Hospital in October 1934, with a diagnosis of cholecystitis and cholelithiasis. Cholecystectomy and choledochotomy was performed with the patient under ether anesthesia. The abdomen was closed with through-and-through retention sutures of silkworm gut.

The patient became critically ill after the operation. Generalized peritonitis developed, and on the fourth postoperative day there was a severe infection of the wound. The retention sutures of silkworm gut did not hold, and there was complete separation of the wound. The patient died on the sixth postoperative day. The dehiscence was of the stage 2 type.

The patient had diffuse peritonitis with a severe infection of the wound, and the peritonitis was the cause of the patient's death.

CASE 18.—A man aged 53 was admitted to the New York Post-Graduate Medical School and Hospital in February 1935, with carcinoma of the recto-

sigmoid. Operation with the patient under ether anesthesia revealed a large carcinoma, which was adherent to the base of the bladder. A one stage abdominoperineal resection was performed. The abdomen was closed with through-and-through retention sutures of silkworm gut.

Generalized peritonitis developed, and on the fourth postoperative day there was a severe infection of the wound. When some of the sutures were removed there was a protrusion of the small intestine. The patient died on the ninth postoperative day. The dehiscence was of the stage 3 type.

The patient's death was due to generalized peritonitis, and there was a marked infection of the wound which resulted in a dehiscence. Peritonitis was the cause of death.

CASE 19.—A man, aged 49 was admitted to the New York Post-Graduate Medical School and Hospital in March 1935, with a diagnosis of cholecystitis and cholelithiasis. Cholecystectomy was performed with the patient under ether anesthesia. The peritoneum was closed with a continuous suture of no. 2 plain catgut and reenforced with three interrupted sutures of plain catgut. The fascia was closed with a continuous suture of no. 2 chromic catgut and reenforced with two sutures of chromic catgut sutures. Four retention sutures of silkworm gut were used and the skin was closed with silk sutures.

The patient's convalescence was uninterrupted except for a moderate degree of distention, but on the sixth postoperative day there was a slight serosanguineous discharge. The wound was inspected and strapped, and I did not believe that there was complete dehiscence. On the eighth postoperative day there was still more discharge, and when the silk sutures were removed the upper third and the lower third of the wound had completely united, but there was a complete separation in the midthird and a portion of the omentum protruded on the abdomen. This was replaced in the abdomen, and the wound was tightly strapped with adhesive tape. The patient left the hospital twenty-one days after the operation. The dehiscence was of the stage 3 type.

The wound to date is firm, but it is impossible to state whether there will be an incisional hernia. There was no evidence of infection to account for the dehiscence.

COMMENT

An early diagnosis of this serious complication is most essential, and the one diagnostic feature is a serous or serosanguineous discharge. When this is profuse the patient may complain of feeling warm fluid on his abdomen or the bedding may be saturated from the discharge. When the discharge has been profuse, the condition is immediately detected, but in cases of only moderate serosanguineous discharge, unless the wound is carefully inspected daily, an early dehiscence might be easily overlooked. For that reason many wounds are considered to be healing by primary union when they have actually had a partial dehiscence. The condition is not detected by the house staff on dressing the wound, as they are not experienced in looking for such a condi-

tion and attribute the serosanguineous discharge to a hematoma, which is usually not true in a case of celiotomy.

Dehiscence of the wound carries a rather high mortality. Meleny and Howes found a mortality of 44 per cent, Colp of 28 per cent, Grace of 39 per cent, White of 55 per cent, Maes, Boyce and McFetridge of 26 per cent and Sokolov of 33 per cent. The mortality in the cases reported in this paper was 16.7 per cent. When the three fatalities are reviewed (cases 13, 17 and 18) it can be seen that the primary cause of death was diffuse peritonitis. The uncomplicated cases of dehiscence of the wound rarely cause death if one is constantly watching for the first signs of this tragedy.

Dehiscence of the wound has caused me more consternation than any other sequela of abdominal operation. Such a high percentage of dehiscence of the wound as compared to the reports from other clinics has caused me to adopt numerous methods of wound closure, as attested by the case reports. In view of this appalling number of cases I have used both continuous and interrupted sutures of catgut of different makes and have relied on both plain and chromic catgut with additional reenforcement from sutures of silkworm gut. The length of time the retention sutures are left in seems to have little effect, as in most cases dehiscence occurs about the seventh day, and this is before retention sutures are removed. Baldwin [9] seems to think that the problem can be solved by allowing retention sutures to remain in for fifteen days.

Silk sutures have been used in 25 cases, but after using them in a case in which an infection lasted for six months I discontinued this method of closure and now use through-and-through sutures of heavy silk or of dermal suture material, which are removed on from the eighth to the tenth day. In this way no nonabsorbable material is buried in the tissue, and catgut is entirely eliminated. There is nothing original in this method of closure. The late Dr. Joseph Price used it over fifty years ago. His associate Dr. J. W. Kennedy [11] has continued using this method of closure, and in their combined experience they have not had a single case of dehiscence of the wound or death from infection of a wound. The reasons for not using catgut will be explained in the following paragraphs.

In view of the high percentage of cases of dehiscence of the wound, it seemed to me that there must be some other factor or factors than the explanations usually given for dehiscence, such as the type of closure, the make of catgut, infections of the wound, type of incision, respiratory infections, general debility of the patient or the choice of anesthesia. For that reason it seems logical to assume that a certain per-

11. Kennedy, J. W.: Tragedies of the Abdominal Incision, Am. J. Surg. **25**: 512 (Sept.) 1934.

centage of patients might be considered allergic to catgut. It is only necessary to recall that one is relying on the protein of a sheep for keeping the tissues approximated.

In reviewing the case reports, the various authors do not seem to stress the fact that dehiscence of the wound in all probability is merely a more advanced stage of the same process that produces incisional hernia and causes inguinal hernia to recur after the many different methods of repair that have been advocated.

Patients were first considered allergic to catgut in 1929, after I had had 3 cases of dehiscence of the wound three weeks in succession, when no reasonable explanation could be given for this complication. I then discussed with Dr. Will Cook Spain the possibility of allergy being an explanation for dehiscence of the wound and incisional hernia. He felt that the foreign protein of a sheep introduced into a human being in certain instances would produce sufficient allergic reaction to account for the absorption of the catgut and leave the wound insecurely united.

After trying to get different makes of catgut in solution so as to try out intradermal injections of different concentrations, it occurred to Dr. Spain that we should use fresh sheep gut and in this way avoid any chemical reaction from the prepared gut. Babcock [12] has recently referred to allergy to catgut, but he used prepared gut and buried it beneath the skin. His reactions might possibly be due to a chemical constituent and not a true reaction to foreign protein. Dr. Spain had his technician in the "allergy clinic" at New York Post-Graduate Hospital prepare solutions of the fresh sheep gut in concentrations of 0.8 and 0.01 per cent, and these were used for the tests. After Dr. Spain gave instructions to the technician for the intradermal injections, we attempted in the "stomach clinic" of the fourth division of the Bellevue Hospital and in the wards of the fourth surgical division to determine if patients were susceptible to sheep protein. This was done on 112 patients. We aimed to take patients who had not been operated on, as we felt that the previous use of catgut might desensitize a sensitive patient or after a longer interval might make him sensitive to sheep protein. In our group of patients there were 9 who definitely showed a moderate reaction after the concentrated injection of the sheep gut.

Of the 112 cases tested, there were 103 in which the results were negative. There were 9 definite reactions with the 0.8 per cent solution in from ten to fifteen minutes after the intradermal injection. There were no reactions with the 0.01 per cent solution.

As I realized that dehiscence of the wound might possibly be due to an allergic condition, I believed that rather than try to detect the patients that were sensitive to the sheep protein, a different method of wound

12. Babcock, W. Wayne: Catgut Allergy, Am. J. Surg. **27**:67 (Jan.) 1935.

closure was logical. For that reason I have adopted the technic originally used by Price of using through-and-through sutures of braided silk or of dermal suture material and in this way avoid any nonabsorbable material being permanently buried in the wound. This method of closure has been used in 43 cases, and so far I have been favorably impressed by the lack of reaction from the wound.

SUMMARY

One should remember that there are two types of dehiscence of the wound. The first type is associated with a severe infection of the wound. In this type the disruption occurs after any method of closure. The fatalities in this series occurred in the 3 cases with severe infections of the wound associated with generalized peritonitis. The wounds in 2 of these cases were closed with through-and-through sutures. The second type of dehiscence is the one without infection of the wound, and with this type there are no other complications to account for the dehiscence. The catgut seems to be absorbed, and an allergic reaction may be the explanation for this catastrophe.

In the 19 cases in this series the dehiscence has been classified as of one of three stages. In stage 1 there is separation of the peritoneum and the posterior sheath of the rectus abdominis muscle and partial separation of the anterior sheath of the rectus abdominis muscle. It is accompanied by a moderate serosanguineous discharge. There were 4 cases of this stage of dehiscence. In stage 2 there is complete separation of all the layers of the abdominal wall, and when the sutures are removed from the skin the abdominal organs are exposed but do not protrude. There were 9 cases of this stage of dehiscence. In stage 3 there is complete separation of the abdominal wound with a protrusion of a viscus on the abdominal wall. There were 6 cases of this stage of dehiscence.

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ETHYLENE GLYCOL AND MAGNESIUM SULFATE PASTE IN TREATMENT OF INFLAMMATORY PROCESSES

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A pyogenic infection, whether fulminating or of low grade, represents one of the most common, and occasionally one of the most serious, conditions a physician is called on to treat. As is well known, the symptoms of an infection are local pain and swelling accompanied by heat and redness. The important aim of treatment is twofold: first, to prevent a spreading of the infection, and second, to relieve the symptoms. It seems worth while to describe a preparation of ethylene glycol and magnesium sulfate paste which has effected excellent results in serious as well as in trivial infections throughout a period of two years.

As the aim in treatment is to localize the infection by means of ointments or wet dressings, it would seem that a preparation of ethylene glycol and magnesium sulfate, both of which have hypertonic properties and can be kept on continuously, would assist greatly in overcoming a spreading infection or in completely aborting a less severe inflammatory process. The increase in local heat is due to hyperemia of the area under consideration. The swelling is the result of inflammatory edema. First, there is a filtering out of plasma from the blood vessels, and later the leukocytes migrate from the vessels to the involved area. Finally, red corpuscles escape passively to the outside. The pain of inflammation probably has two causative factors: distention of the sensitive tissues by the accumulating inflammatory exudate and an involvement of the nerve endings by bacterial poisons.

The plasma which filters through the capillaries soon forms a clot, since it has the same properties as the circulating plasma. The bacterial action on the cellular structures produces thromboplastin, which results in a change of the fibrinogen to fibrin, with a resulting clot, and for that reason the sooner the infection is localized the less induration there will be in the part.

Ethylene glycol is a substance that will carry magnesium sulfate as a paste, and the two chemicals have hypertonic properties. Glycerin was tried, but a paste cannot be made from it and magnesium sulfate. Certain technical difficulties are encountered in preparing an ethylene

glycol-magnesium sulfate paste; therefore, some consideration should be given to the preparation of the product. It is necessary to use approximately 60 per cent magnesium sulfate and 40 per cent ethylene glycol by volume. The exact proportion varies with the different preparations of magnesium sulfate. One should use U. S. P. magnesium sulfate manufactured by a reliable chemical house. The ethylene glycol should be brought to a boil and the magnesium sulfate slowly added to the glycol preparation and thoroughly stirred until the solution becomes adherent to the stirring rod. Then it is transferred to an electric mixer and kept in constant motion for from twenty to twenty-five minutes. A chemical change takes place when the two ingredients are mixed, which is manifested by an elevation of temperature; so the boiling of the ethylene glycol is essential in preparing the paste. One then has a thick paste, which should be allowed to stand for ten days before it is used. The preparation should be stirred daily for five minutes during this period. The paste is of a semisolid consistency and can be applied thickly over the affected area and covered by a dressing. It is usually necessary to change the paste every eight hours in cases of severe cellulitis. In cases of localized infection such as a furuncle it can be applied and the area left uncovered. The paste should be put on at frequent intervals. The object in using this preparation is to have a medicament with hypertonic properties, so that continuous osmosis will take place in the inflammatory area and by this means the infection will be localized and the edema relieved and as a result the pain greatly diminished, if not entirely overcome.

During the two year period that the preparation described has been used, more than one hundred inflammatory conditions have been observed, which have ranged from simple furuncles to severe cellulitis with lymphangitis and even to furuncles of the upper lip and around the naris. The results have been most astounding in the severe type of cellulitis. On two occasions the patient had been suffering from severe infection of the foot with extensive lymphangitis and cellulitis of the leg and had been referred for hospitalization and operation; the cellulitis in both instances subsided within five days, without surgical intervention. The preparation was first used for this type of infection, and the results have been more than gratifying.

For less severe infections the preparation has proved equally effective, and it has a definite field of application in the treatment of ordinary furunculosis or low grade infection. If the mixture is applied early in the treatment of a furuncle, it frequently aborts the process within from forty-eight to seventy-two hours, and if the condition does not subside, at least the furuncle is more quickly localized. The preparation has a wide field of application in a ward service where continuous wet

dressings are indicated, as it will diminish the amount of nursing care required in such cases.

The preparation involves little expense and requires a minimum outlay of time by both the hospital and the nursing staff. It exerts a continuous osmosis on the affected area. The preparation is definitely indicated in the treatment of pyogenic infections of the cervical lymph glands, lymphangitis and cellulitis of the extremities. Also furuncles around the upper lip and naris respond readily to the treatment.

COMMENT

There are three reasons for using the ethylene glycol and magnesium sulfate paste: 1. It acts more rapidly than wet compresses of magnesium sulfate or other ointments. 2. It is more uniformly successful in arresting or localizing infections than other methods of treatment. 3. It acts continuously and therefore saves nursing care.

130 East Seventy-Ninth Street.

ARTHRITIS AND INJURIES TO JOINTS

DAVID H. KLING, M.D.
LOS ANGELES

The systemic phase of arthritis and rheumatic conditions has been overemphasized in recent papers, with the result that comment revolved mainly around tonsils, teeth, the gastro-intestinal tract and other possible foci of infection. Expositions have been presented of conflicting bacteriologic and serologic findings, of constitutional and endocrinologic hypotheses and, finally, of rigorous and often unbalanced diets. Little has been said about the joints, and still less is done for the joints in the management of arthritis.

A patient recently appraised the situation truthfully: "Why, you are the first doctor who ever looked at my knees! They pulled my teeth, took out my tonsils and gave me shots and diets, but they never bothered about my knees." As a result of her treatment this woman has a flexion contraction of both knees of 90 degrees and is totally crippled. With a little attention to the joints and with simple appliances this could have been prevented.

Since the pioneer work of Goldthwait the orthopedic and the industrial surgeon have not lost sight of the importance of the mechanical factor in the function of the joints. That arthritis is primarily a disease of the joints must be emphasized. Investigation, therefore, should start and center around joints. Fewer generalities and more definite knowledge of the structure, the function and the pathology of the joints is necessary in the fight against this widespread and disabling disease.

THE EFFECTS OF DIRECT INJURY ON JOINTS

Every injury provokes a twofold effect. First, the joints suffer mechanical damage ranging from a tear in the capsule, with effusion, to detachment and laceration of cartilage or fractures of the articular surfaces. Second, the joints react to the trauma, the synovial tissue by inflammation and secretion, the bone by a resumption of the osteogenetic functions which lead to production of normal and abnormal bone. The central portion of the articular cartilage, which does not possess a blood supply, cannot react actively, but it undergoes degeneration.

Read in part before the Industrial Accident Section of the Los Angeles County Medical Association, Nov. 8, 1934.

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The first result of an effusion is distention of the capsule and increase in the intra-articular pressure. This alone is a source of irritation, as most joints are normally under negative pressure. In order to accommodate a large effusion the joint is forced into a pathologic position, which, provoking muscle spasm, limits the normal range of motion.

Recent traumatic effusions are hemorrhagic, but the blood is augmented by an increase in synovial fluid almost immediately after the injury. This intimate and direct reaction of the synovial membrane is demonstrated by examination of the joint fluid. If a hemorrhagic effusion is centrifugated, it is found that the supernatant fluid is not merely blood plasma but contains a mucinous body which gives rise to peculiar precipitative phenomena (fig. 1). If a drop of diluted acetic acid is put into the plasma, a faint cloud appears. In the joint fluid a closed membrane is formed by the precipitation of a mucin-like body.

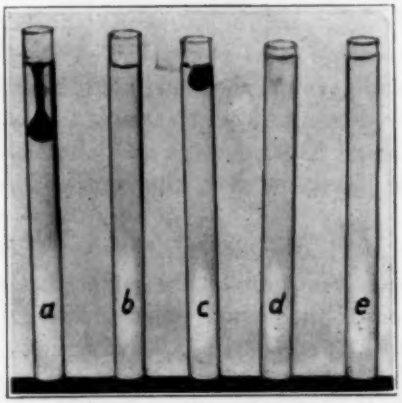

Fig. 1.—Tubes *a* and *c* show sac and tube formation in synovial fluids; tube *b*, a very thin sac in synovial fluid; tube *d*, turbidity in a pleural effusion (a positive Rivalta reaction), and tube *e*, absence of turbidity (a negative Rivalta reaction) in fluid from a serous ovarian cyst.

In extensive studies on the nature and origin of synovial fluid,[1] I have proved that the mucinous bodies are a secretory product and the characteristic constituent of normal and pathologic joint fluid. They were found in over 95 per cent of the traumatic effusions tested. Owing to their presence the specific viscosity of over 90 per cent of the traumatic effusions was much higher than that of blood plasma.

The irritation of a hemorrhage into the joint is therefore promptly answered by hypersecretion of the synovial fluid. If the effusion remains in the joint for a long time, permanent irritation is established with results that are clearly demonstrated in the joints of hemophiliacs.

1. Kling, David H.: Nature and Origin of Synovial Fluid, Arch. Surg. **23**: 543 (Oct.) 1931.

Here repeated hemorrhages occur which it is not advisable to evacuate. The synovial membrane is thickened and inflamed; the blood is broken down, and fibrin precipitates and is organized, with the formation of adhesions. The cartilage is partly degenerated by the prolonged pressure and partly eroded by an inflammatory reaction of the synovial tissue or underlying bone, which leads to irregularities of the articular surfaces and to the production of osteophytes. In short, a picture of severe arthritis with the characteristics of both atrophic arthritis and osteo-arthritis is the end-result of repeated traumatic effusion.

In severe injuries I have demonstrated the presence of fat as well as of blood in the effusions.[2] This fat is torn loose from the fat pads or from the bone marrow. In the former instance it indicates an injury

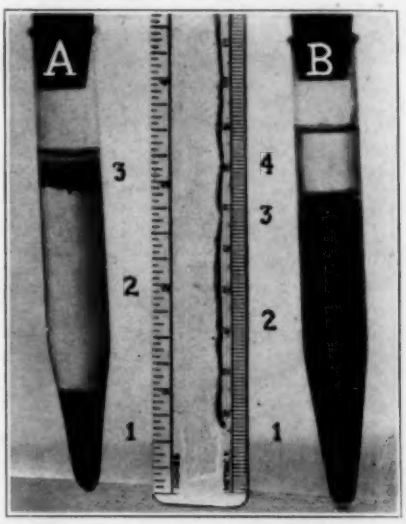

Fig. 2.—Hemorrhagic traumatic synovial fluid containing fat. *A* shows fluid with a small amount of olein centrifugated into three layers; the serum is clear. In *B* the fluid contains a large amount of olein and is separated into four layers. In both *A* and *B* the first layer is blood corpuscles; the second, serum, and the third, solid fat (palmitin and stearin). The fourth layer, in *B*, is liquid fat (olein).

to the intra-articular cartilage or to the ligaments and consists chiefly of palmitin and stearin, which are solid at room temperature. In the second case it indicates an articular fracture and consists chiefly of olein, which has a melting point of —4 C. and is therefore liquid at room temperature. Fat in joint effusions is demonstrated simply by centrifugation. At the bottom appears a layer of blood corpuscles;

2. Kling, David H.: Fat in Traumatic Effusions of the Knee Joint, Am. J. Surg. **6**:71 (Jan.) 1929.

above that, the plasma, and in a third layer, solid fat (fig. 2*A*). If liquid fat is present, a fourth layer appears on top (fig. 2*B*).

In cases of intra-articular fracture the effusions can contain also bone marrow cells.[3] However, the cytology of joint fluids is complicated by the presence of numerous cells, in various stages of degeneration, which may resemble bone marrow cells. A little known form of degeneration of leukocytes in effusions and various exudates consists of fragmentation and concentration of the nucleus. The leukocytes then closely resemble nucleated red cells colored with Wright's stain

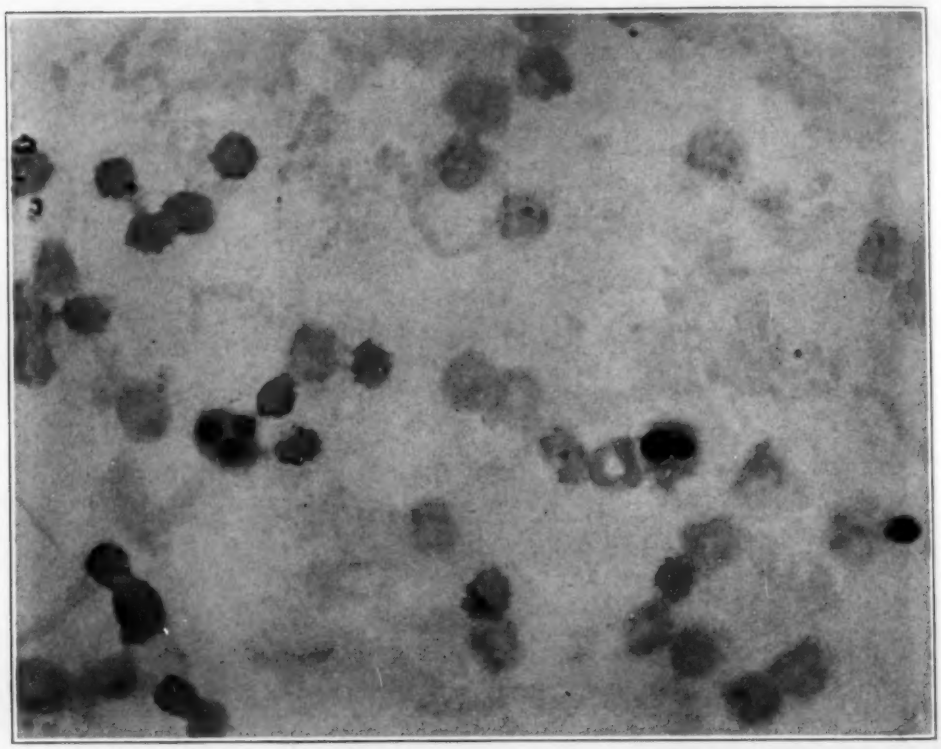

Fig. 3.—A smear from synovial fluid showing degenerated leukocytes, with fragmentation and concentration of the nucleus, resembling nucleated erythrocytes.

(fig. 3). Such degenerated leukocytes are present not only in traumatic but also in inflammatory effusions, as pointed out by Risak and Winkler [4] and by McEwen.[5]

3. Kling, David H.: Erythroblasts and Myelocytes in Traumatic Effusions of the Knee Joint, Am. J. Surg. **7**:824 (Dec.) 1921.

4. Risak, Eugene, and Winkler, Walter: Zur Klinik und Pathologie der Gelenksergüsse, Deutsches Arch. f. klin. Med. **165**:129, 1929.

5. McEwen, C.: Cytologic Studies on Rheumatic Fever: Cells of Rheumatic Exudates, J. Clin. Investigation **14**:190 (March) 1935.

The presence of fat in traumatic effusions distinguishes severe injuries from simple tears of the joint capsule. It further emphasizes the necessity of early aspiration of traumatic effusions. Loose bodies consisting of fibrotic fat indicate that fat precipitates and creates a chronic pathologic condition in the joint cavity which finally leads to the development of arthritis.

From the foregoing observations it follows clearly that any residue of an injury, such as particles from an effusion, a depressed condyle of a tibia, a piece of patella, a loose piece of cartilage or a torn ligament may provoke a permanent state of irritation which finally results in osteo-arthritis (figs. 4 and 5). Not only intra-articular fractures but also malunited extra-articular fractures can produce changes in the

Fig. 4.—*A* shows a recent fracture of the patella, and *B*, the same patella several years later, with a spur formation at the distal end.

joints which terminate in arthritis; for instance, arthritis of the elbow may follow displacement of the head of the radius, and arthritis of the ankle or subastragaloid joints, fracture of the tibia or the os calcis. Restoration of the normal anatomic position of the fragments, therefore, is imperative in order to prevent the onset of traumatic arthritis.

For the industrial surgeon a differential diagnosis of traumatic and inflammatory joint effusions is of special interest. When the claimed injury is not recent the presence of blood cannot be a criterion because a hemorrhagic effusion could already have been absorbed. As an indicator of the source of effusion fluid I have used [6] the bilirubin content,

6. Kling, David H.: Bilirubin in Effusions of the Joints, Arch. Surg. **20**: 17 (Jan.) 1930.

which represents the end-product of a hemorrhage into the joint cavity. If, for instance, an injury occurred six weeks ago and an effusion is now present, its bilirubin content will be higher than that of blood serum. Simple methods of estimating the bilirubin content are the van den Bergh and the icteric index tests. The icteric index of traumatic effusions is above 5; that of inflammatory effusions is invariably below 5. Apart from trauma only a few conditions, e. g., hemophilia, tabetic atrophy, xanthoma or sarcoma, cause spontaneous bleeding into

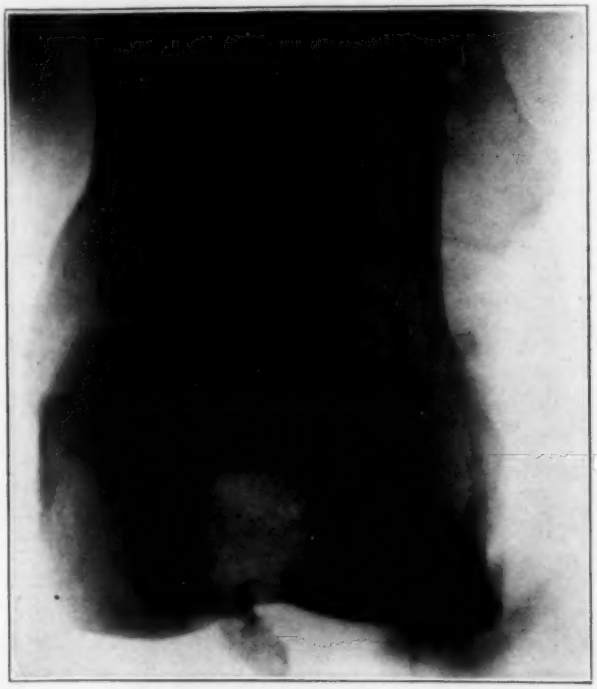

Fig. 5.—Habitual dislocation of the patella, with osteochondromatosis of the intercondylar notch of the femur.

the joints and a high bilirubin content of the effusions. The special symptomatology of these rare conditions leads to the correct diagnosis.

As an illustration of the usefulness of the estimation of bilirubin I give the following abstract of a recent case:

A white man 42 years of age, accustomed to rigorous athletic exercises, e. g., sprinting, had pain and swelling of the right ankle. Roentgenograms revealed a united linear fracture of the fourth metatarsal bone, with good callus formation. The patient could not state definitely the time of fracture. He was advised by the family physician to rest as much as possible and received physical therapy of the foot. Swelling of the leg and an effusion of the right knee developed. The patient called in a second physician, who without any knowledge of the roentgeno-

grams made a diagnosis of phlebitis and infectious arthritis. He advised hospitalization and wet applications. The swelling of the leg diminished, but the effusion of the knee joint persisted. The teeth were regarded as a focus of infection, and their removal was considered. When I was called in consultation 40 cc. of slightly turbid fluid was aspirated. On examination the icteric index was 12, showing definitely that the effusion originated from a hemorrhage. This was further supported by the presence of red blood cells in the sediment, by negative cultures and by only a slight increase in the rate of sedimentation of the blood The infectious etiology being ruled out, it was unnecessary for the patient to submit to dental surgery. With the patient resting in bed the effusion was absorbed within a week. Normal function was restored by diathermia and massage of the leg. Slight genu valgum, pronounced pronation of the feet and depression of the metatarsal arches were found and were corrected by arch supports.

The strain caused by the static imbalance of the lower extremities evidently acted as a predisposing cause of the symptomless fracture discovered by roentgenogram and of the traumatic arthritis of the knee joint.

THE EFFECTS OF INDIRECT INJURY ON JOINTS

The most common form of chronic arthritis is osteo-arthritis or hypertrophic arthritis. Its entire etiology is still controversial. This much, however, is certain: The first stage is degeneration of articular cartilage. Articular cartilage is very susceptible to injury even though the injury is not sufficient to be visualized in roentgenograms. It may be damaged by abnormal configuration and function of the joints as a result of previous injury or disease or of congenital malformation, such as dislocation of the hip or valgus or varus deformities of the knees and the feet. Continuous and excessive pressure and loss of normal contact are especially destructive to articular cartilage. The first step in the development of osteo-arthritis, degeneration of articular cartilage, is thus linked to trauma. The onset of symptoms is frequently traced to a trivial injury caused by a violent motion or a sprain.

The subsequent reactive manifestations, such as eburnation of the bone when it is deprived of its protecting cover of cartilage, the formation of osteophytes and the hypertrophy of synovial membrane, are at least in part induced by degeneration of the cartilage. That trauma continues to be a factor during the later stages is evidenced by clinical and pathologic features. Contrary to the current opinion that effusion is rare in osteo-arthritis, I have found periodic marked increases of synovial fluid in a large group of patients observed for a number of years. The fluids have had high viscosity and have contained a small number of cells, chiefly monocytes and synovial lining cells. This has indicated hypertrophy and hypersecretion of the synovial membrane. In about 30 per cent of the fluids I have noticed red particles which gave the chemical reaction of blood. They were therefore the precipitated remnants of small hemorrhages in the joint cavities of the patients.

The combination of constitutional anomalies with trauma in the etiology of chronic arthritis is demonstrated in Perthes' disease, habitual dislocation of the patella (fig. 5) and osteochondritis dissecans (fig. 6). The latter is of especial interest to the industrial surgeon on account of the possible development of clinical symptoms after trivial injury. I have proved that as long as the necrotic shell of bone and cartilage remains attached there is no effusion and no interference with joint function. After strain or other occupational trauma the fragment can become detached and form a loose body impinging on various parts

Fig. 6.—Osteochondritis dissecans of a knee joint and a loose body in the popliteal pouch. *A*, the anteroposterior view, shows the detachment of the necrotic shell beginning, and *B*, the lateral view, the loose body in the suprapatellar pouch.

of the synovial membrane, causing inflammation, effusion, limitation of motion and finally deformity of the joints.

Trauma as an etiologic factor is not confined to nonspecific arthritis. Tuberculous arthritis may be provoked by an injury. Of a group of 11 patients with syphilitic arthritis, 4 said they had had a joint injury. It has long been known and has been confirmed by recent investigations that trivial injuries may precipitate syphilitic manifestations. A positive

Wassermann reaction of the joint fluids and the blood then leads to discovery of the syphilitic infection.[7] Other criteria confirm the syphilitic nature of the synovitis. The following case illustrates the importance of the consideration of syphilis in traumatic surgery:

A mail carrier 39 years of age claimed that he slipped and twisted the right leg eleven days before admission to the hospital. During the next few days he noticed swelling of the knee joint, pain and limitation of motion. The diagnosis was traumatic effusion, and 40 cc. of turbid fluid was aspirated. The icteric index of the fluid was low, and blood cells were absent. This ruled out a traumatic origin of the effusion. The Wassermann reaction of the joint fluid was strongly positive. The patient refused to permit a test of the blood and said that he had not had syphilitic infection. The joint fluid was aspirated seven times in the following two months to test recurrence of the effusion. The patient then permitted a test of the blood. Only after a positive reaction was found by several laboratories did he submit to antisyphilitic treatment. The effusion then disappeared, and the joint was restored to normal.

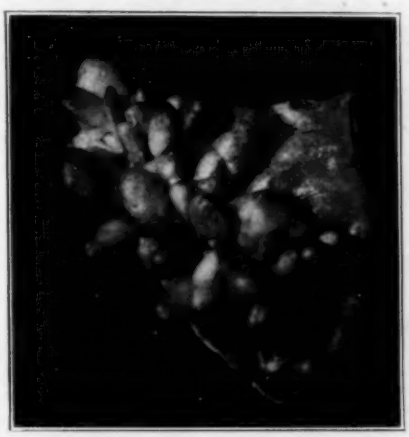

Fig. 7.—Synovial tissue in villous arthritis.

As a result of injury, chronic irritation and hypertrophy of the synovial membrane may develop and lead to the formation of villi and to persistent effusion. By examination of the joint fluid the diagnosis of villous arthritis (fig. 7) can be established.[8] The total number of cells is small, and in a differential count the synovial lining cells are found to constitute more than 15 per cent (fig. 8). This is an indication

7. Kling, David H.: Wassermann Reaction in Joint Fluids, Am. J. Syph. **13**: 596 (Oct.) 1929; Syphilitic Arthritis with Effusion, Am. J. M. Sc. **183**:538 (April) 1932. Kling, D. H., and Pincus, J.: Further Investigation on the Wassermann Reaction in Joint Fluid, Am. J. Syph. **15**:376 (July) 1931.

8. Kling, David H.: The Synovial Cells and Joint Effusions, J. Bone & Joint Surg. **12**:867 (Oct.) 1930.

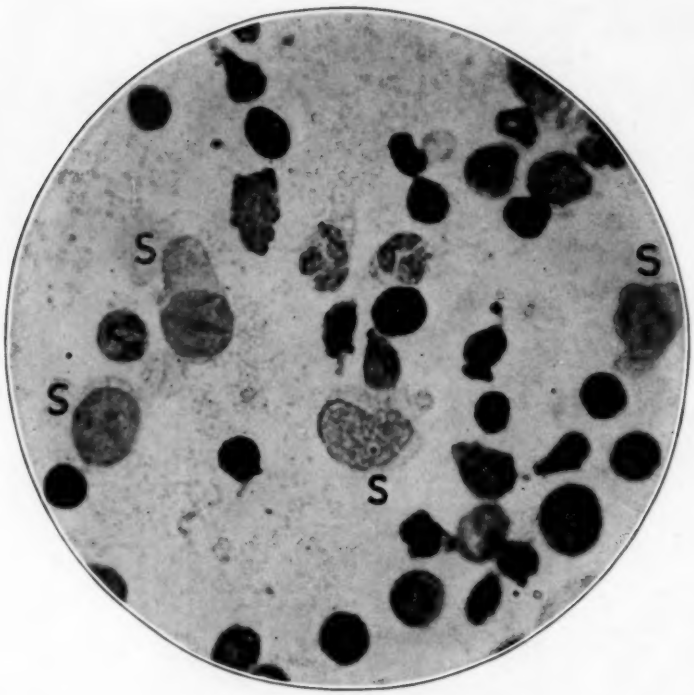

Fig. 8.—A smear from the synovial fluid of villous arthritis. *S* indicates synovial cells.

Fig. 9.—Inflation of the knee joint with air, showing hypertrophic synovial membrane in the suprapatellar pouch.

for synovectomy, which alone can restore normal conditions. Inflation of the joint with air in this and other form of synovitis is sometimes useful to visualize the configuration of the joint, the extent of the involvement and the presence of adhesions (fig. 9). The occurrence of air embolism, reported in the United States and abroad, is due to faulty technic. Before injection of air or any other gas into the joint cavity it is necessary to ascertain that no vessel has been punctured. This is done by inspection of the aspirated effusion or by injection and aspiration of a saline solution before air is introduced.

In recent years, stimulated by the extensive anatomic studies of Schmorl, surgeons began to realize the importance of injuries to the intervertebral disks and the nucleus pulposus in the development of spondylitis and other pathologic conditions of the spine. Sashin [9] was one of the first in this country to correlate roentgenographic evidence of herniation of the nucleus pulposus with previous trauma.

SUMMARY AND CONCLUSIONS

Single severe injuries to the joints as well as mild repeated trauma are important factors in the etiology of arthritis. The lesion and the irritation of the soft tissues and the bone produce inflammatory reactions which lead to hypersecretion and hypertrophy of the membrane and to deformation of the articular surfaces.

The frequent affection of articular cartilage by trauma leads to degeneration and erosion and may provoke the development of osteo-arthritis. Trauma not only presents the first link in the chain of pathologic changes in unspecific osteo-arthritis but may open a path for the invasion of the joint by nonspecific organisms as well as by the tubercle bacillus and Spirochaeta pallida.

The examination of joint effusions is an important means of determination of the severity of an injury and of differentiation between traumatic and inflammatory effusions and between specific and nonspecific conditions of joints. The aspiration of the joint evacuates pathologic products from the joint cavity and reduces irritation and thus promotes the restoration of normal conditions.

Requirements for the prevention of arthritis after injuries of joints or in the vicinity of joints are reduction of fractures, early removal of loose or lacerated cartilage and repair of ligaments. Proper therapy, with rest, fixation of the fracture and resumption of motion, is of the utmost importance; it requires thorough understanding of the physiology and pathology of joints, and great clinical experience. The early recognition of constitutional or acquired anomalies and diseases which

9. Sashin, David: Intervertebral Disk Extensions into the Vertebral Bodies and Spinal Canal, Arch. Surg. **22**:527 (April) 1931.

are apt to traumatize or invade the joints, such as osteochondritis dissecans, Perthes' disease, genu valgum and genu varum, syphilis, tuberculosis and endocrine disturbances, opens a way for preventive measures to reduce the development of chronic arthritis.

My plea to restore to the joint priority in the consideration of the problems of arthritis is intended not to minimize extra-articular factors but to furnish a firm groundwork of controlled facts, which alone assures steady progress in the recognition and therapy of disease.

1930 Wilshire Boulevard.

EFFECTS OF CIRCULATORY DISTURBANCES ON THE STRUCTURE AND HEALING OF BONE

INJURIES OF THE HEAD OF THE FEMUR IN YOUNG RABBITS

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BOSTON

Adequate nutrition is essential for the normal structure and function of bone tissues and for repair after injury. The anatomic relations of joints and their articular cartilage, the growth of bone in the metaphyses and the repair of fractures and dislocations are specific problems of the skeletal system in which nutrition is a determining factor. Studies of diseases and injuries of bone and their repair demand a knowledge of the intrinsic vascular pattern and of the opportunity for collateral circulation of most bones and, in particular, of certain bones and epiphyses.

Many reports, some speculative and conflicting, have included a discussion of the etiology and repair of various forms of osteochondritis, aseptic and septic necrosis, epiphyseal slipping or separation and other more or less obscure changes in the epiphyses and in their cartilage. There is, further, some doubt regarding the normal circulation of bone and the importance of the various sources of blood and collateral circulation. Many investigators have expressed the opinion that trauma is important in producing changes in bone; others have concluded that trauma, except in fractures and dislocations, affects bone only by mechanical distortion of a primary osseous defect. The latter theory presupposes a vascular disturbance, with or without a mild infectious agent, but it is confronted by discordant statements concerning the vascular pattern of bone.

In a recent experimental study [1] infarcts were produced in the femur in rabbits by injecting a suspension of particulate charcoal into the principal nutrient artery of the shaft. The changes produced were correlated with a review of the clinical disorders in human tissues and with experimental studies concerned with aseptic necrosis in bone and the blood supply of these tissues. Further studies [2] demonstrated that

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From the Henry Baird Favill Laboratory of St. Luke's Hospital, Chicago, John Jay Borland Fellowship for Clinical Research, and the University of Alabama Medical School, University, Ala.

1. Kistler, G. H.: Sequences of Experimental Infarction of the Femur in Rabbits, Arch. Surg. **29**:589 (Oct.) 1934.

2. Kistler, G. H.: Surg., Gynec. & Obst. **60**:913, 1935.

agglutinated staphylococci act as emboli and, when living, infect the infarcted tissues. The infarcts produced occurred regularly beneath epiphyseal and other cartilage, tissues that are vulnerable because of a peculiar capillary blood supply and an inadequate collateral circulation. No noteworthy vascular connection between the epiphyses and the diaphysis of the femur was present in these growing rabbits. In the small septic infarcts, clumps of staphylococci were noted in the lacunar spaces between columns of calcified matrix projecting into ossifying epiphyseal plates and other cartilage. The suggestion was made then that embolic occlusions of end-capillaries beneath epiphyseal plate cartilage cause infarcts in the shaft of the femur and beneath articular cartilage cause subchondral lesions, such as tuberculosis or other infections in the epiphyses, even when the epiphyseal plate cartilage has disappeared and longitudinal growth has ceased.

The head of the femur is often the site of infection, injury and necrosis with or without clearly associated trauma. The changes are those which occur in epiphyses generally and those associated with weight bearing and the particular anatomic structure of the head and neck of the femur. These are often attributed to a vascular disturbance of the epiphysis with consequent damage of the tissues and some deformity of the part by mechanical stress. The capital epiphysis especially is subject to vascular disturbances. The opportunity for the development of collateral circulation here is limited. The entire head is intracapsular, being covered by articular cartilage; the only sources of blood supply are through the ligamentum teres femoris, through the epiphyseal vessels from the periosteal attachment of the capsule at the margin of the head and, in the adult femur, through the vessels of the shaft. Disturbances within the head of a growing femur are distinct from and should not be confused with those of the metaphysis of the shaft or isolated lesions of the epiphyseal cartilage plate.

The damage to osteoid tissue by an injury of the blood supply of the head of the femur and the subsequent repair depend on the importance to normal nutrition of the interrupted blood supply, on the opportunity to obtain collateral circulation and on the presence within the head of anastomoses from the three possible sources of blood. Lexer,[3] Chandler and Kreuscher[4] and many others, by injection experiments and histologic examination, demonstrated the entrance of vessels into the head of the femur through the round ligament which they said were important. Nussbaum[5] and Walmsley[6] refuted the presence of these

3. Lexer, E.: Arch. f. klin. Chir. **71**:1, 1903.
4. Chandler, S. B., and Kreuscher, P. H.: J. Bone & Joint Surg. **14**:834, 1932.
5. Nussbaum, A.: Beitr. z. klin. Chir. **130**:495, 1924.
6. Walmsley, T.: J. Anat. & Physiol. **49**:434, 1915.

vessels. Zemansky and Lippmann [7] produced marked changes and coxa vara deformity of the head of the femur in rabbits 2 weeks of age, but not in adults, by cutting the ligamentum teres. After producing such a lesion in young goats, Graham [8] noted moderate changes indicating a nutritional disturbance. These alterations were not typical of the osteochondritis described by Legg,[9] Perthes [10] and Calvé.[11] Stewart [12] could not regularly produce aseptic necrosis in rabbits and dogs by cutting the round ligament and circumcising the periosteum of the neck of the femur. He said that he considered that the blood supply from the neck is usually sufficient to preserve the vitality of the head, and he made no distinction between growing and adult femurs. The presence of a vascular communication is implied between the diaphysis and its epiphyses through the conjugal cartilage plates. Miltner and Hu [13] produced necrosis of the head by stripping the periosteum of the neck and ligating the neck and the round ligament. Internal weakening and weight bearing resulted in collapse of the epiphysis, lesions they considered comparable to osteochondritis of the head.

Many clinical studies have been published of intracapsular fracture of the femur. Santos,[14] Freund,[15] Speed,[16] Wolcott [17] and others have emphasized the importance of the ligamentum teres in repair and in preventing necrosis and deformity of the fractured segment. Camitz [18] stated that the round ligament alone may prevent necrosis of the proximal fragment. These investigators stated also that the absence of a capsular attachment is a serious handicap to healing and that injury to the capsule and round ligament by dislocation may cause nutritional disturbances of the head. Walmsley studied the head of the femur after the postmortem injection of a dye into the bodies of two boys, 2 and 6 years of age. Some dye was distributed to the tissues of the head

7. Zemansky, A. P., Jr., and Lippmann, R. K.: Surg., Gynec. & Obst. **48**: 461, 1929.

8. Graham, R. V.: M. J. Australia **1**:207, 1930.

9. Legg, A.: Arch. franco-belges de chir. **25**:585, 1922.

10. Perthes, G.: Klin. Wchnschr. **3**:513, 1924.

11. Calvé, J.: Arch. franco-belges de chir. **25**:592, 1922.

12. Stewart, W. J.: J. Bone & Joint Surg. **15**:413, 1933.

13. Miltner, L. J., and Hu, C. H.: Osteochondritis of the Head of the Femur, Arch. Surg. **27**:645 (Oct.) 1933.

14. Santos, J. V.: Changes in the Head of the Femur After Complete Intracapsular Fracture of the Neck, Arch. Surg. **21**:470 (Sept.) 1930.

15. Freund, E.: Virchows Arch. f. path. Anat. **261**:287, 1926.

16. Speed, K.: Ann. Surg. **96**:951, 1932.

17. Wolcott, W. E.: Circulation of the Head and Neck of the Femur: Its Relation to Nonunion in Fractures of the Femoral Neck, J. A. M. A. **100**:27 (Jan. 7) 1933.

18. Camitz, H.: Acta chir. Scandinav. (supp. 19) **68**:1, 1931.

through the vessels of the capsule and the periosteum but none through those of the round ligament. The importance of the blood supply to the head of the femur from the joint capsule was emphasized by Harris,[19] who injected dye into a puppy and into a human fetus. Bentzon [20] injected alcohol about the arteries of the upper epiphysis of the femur in young rabbits and produced a coxa plana deformity. He attributed this result to trauma and blocking of adventitial nerves, with active hyperemia of the head. Stewart observed that circumcision of the periosteum of the neck in rabbits and dogs added no appreciable circulatory disturbance when the round ligament had been cut. Miltner and Hu, however, ligated the neck after stripping off the periosteum, and they demonstrated a greater necrosis of the head when the round ligament was ligated than when it was intact.

There is some uncertainty whether or not the epiphyseal cartilage plate of a growing bone is a barrier to nutrition of the head from the circulation of the shaft. Embolic infarcts, produced experimentally in rabbits, occurred chiefly in the metaphyses beneath cartilage plates, where focal necrosis of bone frequently is present clinically. The adjacent epiphyses were not affected except by direct extension with septic emboli. Both septic and aseptic necrosis within the metaphysis included a definite portion of the growing cartilage plate. Epiphyseal separations occurred along a plane between the necrotic ossifying and the proliferating cartilage tissues where the metaphyseal end-capillaries did not anastomose with the epiphyseal circulation. Charcoal emboli distributed to the vessels of the capsule of the hip joint and the ligamentum teres in young rabbits produced marked necrosis of the tissues of the head, as though no appreciable blood supply were derived from the shaft. Occasionally, however, collateral circulation for repair of the head developed from the shaft through the cartilage plate. Kolodny [21] and Eliason and Ferguson [22] gave as their opinion that a few vessels enter the head from the tissues of the shaft but that they have less importance than the periosteal blood supply which enters the margin of the articular cartilage. Stewart concluded that the vitality of the tissues of the head can be maintained by the circulation in the neck, presumably in a growing as well as in an adult femur.

The existence of end-capillaries in the epiphyses, such as those in the growth centers of the shaft, also has been studied. Phemister,[23] extending the work of Santos, reported clinical and pathologic studies of dislocation and intracapsular fractures of the head of the femur

19. Harris, H. A.: J. Anat. **64**:3, 1929.
20. Bentzon, P. G. K.: Brit. J. Radiol. **31**:439, 1926.
21. Kolodny, A.: J. Bone & Joint Surg. **7**:575, 1925.
22. Eliason, E. L., and Ferguson, L. K.: Surg., Gynec. & Obst. **58**:85, 1934.
23. Phemister, D. B.: Surg., Gynec. & Obst. **59**:415, 1934.

and stressed the need of an adequate blood supply to avoid necrosis and to promote union of a separated fragment. He stated that he had observed little evidence of epiphyseal end-capillaries like those thought to be present in the metaphyses. When septic emboli were directed into the head and great trochanter of the femur, focal subchondral regions of necrosis appeared. These began minutely in the lacunar spaces between columns of calcified cartilage similar to those of the metaphyses following embolic infarction through the principal nutrient artery of the shaft.

Expansile growth of the epiphyses is similar to growth in length in the metaphyses. The latter, possibly, is more rapid because of the abundant blood supply to the proliferating plate cartilage from the epiphysis, as compared with the relatively poor nutrition of articular or other cartilage about the epiphyses. Where growth is active the end-capillaries are long and numerous, conditions favoring the more frequent occurrence clinically of foci of necrosis in some growth regions than in others. A wide metaphysis is considered more vulnerable than a narrow one, because in the wide metaphysis the center is farther from collateral periosteal blood supply. Some expansile growth may continue in an epiphysis after it has united with the diaphysis, thus providing end-capillaries and the possibility of subchondral foci of septic or asceptic necrosis in an otherwise adult bone.

The destruction of an artery to a bone does not duplicate embolism of its branches or end-capillaries within the bone. The large vessels of the medullary tissues may become channels for collateral circulation from another external source. Therefore, a few small emboli may produce greater injury to osteoid tissue than severe trauma.

EXPERIMENTAL METHODS

Experiments were designed to study the normal blood supply and vascular pattern of the head of the growing femur in rabbits and the relative importance of the various sources of blood in maintaining nutrition for normal growth and the repair of injuries. Various operative procedures were performed especially to determine the importance of the ligamentum teres and the capsule of the hip joint as sources of blood to the head in the repair of intracapsular fractures.

The following experiments were performed on one hundred and sixty-six rabbits ranging in age from 12 hours to 35 days: (1) ligation or evulsion of the principal nutrient artery to the shaft, (2) interruption of the vessel that passes through the trochanteric notch, (3) division of the ligamentum teres, (4) division of the ligamentum teres and interruption of the vessels that pass through the trochanteric notch, (5) division of the ligamentum teres and ligation or evulsion of the principal nutrient artery to the shaft, (7) ligation of the neck of the femur with black silk, (8) division of the ligamentum teres and ligation of the neck of

the femur with black silk, (9) fracture of the head of the femur and (10) division of the ligamentum teres and fracture of the head of the femur.

The rabbits were fed stock rations of oats, green vegetables and hay. Each group contained animals of two ages: from 12 hours to 5 days old and about 30 days old. The operations were performed with aseptic precaution with the animals under phenobarbital sodium anesthesia; very young animals required no anesthetic. The principal nutrient artery to the shaft was exposed through an incision on the anterior surface of the upper third of the thigh. It was isolated near its orgin from the lateral circumflex artery and was identified by dissection down to the nutrient foramen, where it was ligated or evulsed outside the cortex of the shaft. Access to the structures within the hip joint was obtained through a similar incision in the thigh with the leg abducted and rotated outward. In some earlier experiments the joint space was opened from above, but was unsatisfactory as the head was not exposed properly and dislocation sometimes occurred later through the opening in the joint capsule. The branch of the deep femoral artery which enters the proximal end of the shaft through the trochanteric notch was isolated and interrupted through an incision laterally over the great trochanter.

The operation usually was performed on the right femur, the left serving as a control. The animal was killed from a few hours to seventy-six days after operation; the femurs were fixed in Klotz' solution no. 1, containing solution of formaldehyde U. S. P. in a concentration of 10 per cent. The bone tissues were decalcified in 4 per cent nitric acid and cut transversely into three segments and then longitudinally into blocks, the number varying with the size of the femur. Blocks of the proximal portions of the femurs, many acetabula and the middle and distal portions of the femurs, when indicated, were then embedded in pyroxylin and paraffin. Many sections at various levels were cut and stained with hematoxylin and eosin. Other sections from animals which had been given intravenous injections of lithium carmine or india ink were examined, stained and unstained.

RESULTS

After operation some of the rabbits showed disability of the leg, the degree depending on the kind of experiment performed and the subsequent changes in the head of the femur. No attempt was made to immobilize the affected leg. Interference with the principal nutrient artery to the shaft, with the vessel that passes through the trochanteric notch or with the ligamentum teres produced no disability or slight disturbance of the leg for about two days. After the more extensive procedures with greater trauma to the soft tissues, the leg was held partially flexed at the hip and knee for a few days; then it was used like the control leg. The leg often was rotated internally at the hip, and the lower portion of the leg and the foot were extended outward from the body, owing to downward flattening and anterior rotation of the head of the femur. Frequently the leg operated on was shorter than the control leg, owing to downward displacement of the head of the femur on the neck or to hypoplasia of the neck itself. The greatest disability occurred when the head separated from the neck or after fracture without permanent fixation of the isolated segment (pseudarthrosis). Even when this took place the rabbit moved about within from six to ten days after operation without favoring the affected extremity and had no noteworthy deformity except a variable degree of shortening and corresponding prominence of the great trochanter. The extent of passive motion of the leg was diminished by fibrous thickening of the joint capsule. In the joints usually one cartilage surface, epiphyseal plate or newly formed cartilage about it was opposite the acetabulum, which had been remolded to fit the contour of the new articulating surface of the femur.

The neck of the femur in some instances was small, and the degree of hypoplasia was proportional to the extent of injury to the head, but it was most marked in young animals. The diameter of the proximal end of the femur was smaller than that of the control bone, owing to diminished growth in the metaphysis of the head. The length of the femur measured from the root of the neck often was less than that in the control, although the total lengths of the bones were the same. Histologic preparations also demonstrated that the portion of the proximal metaphysis of the shaft forming the great trochanter had grown away from the neck.

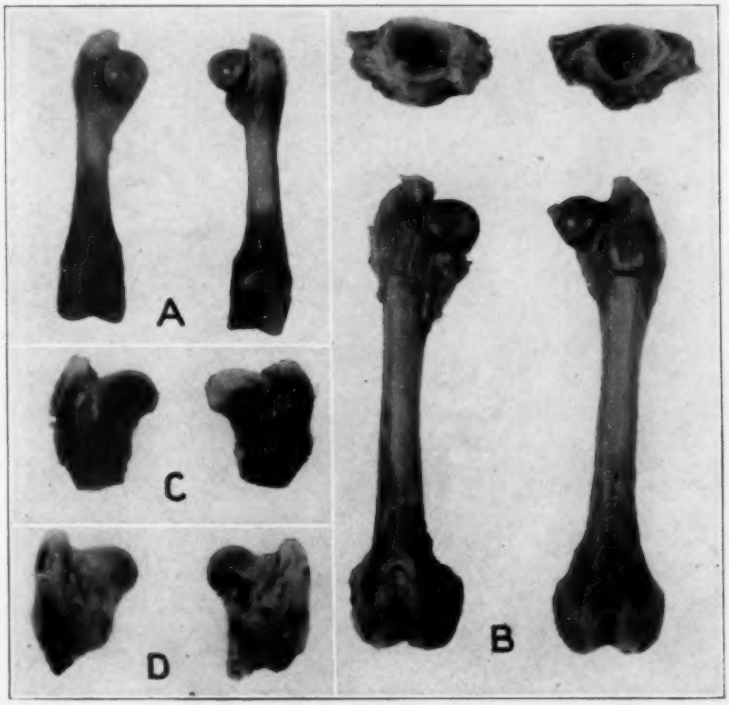

Fig. 1.—The femurs of rabbits after division of the right ligamentum teres. *A*, downward and anterior displacement of the head of the right femur twenty-one days after operation, performed when the animal was 4 days old. The principal nutrient artery to the shaft also was interrupted. *B*, the head and the acetabulum of the right femur are larger than those of the left, and the head is broad (forty-nine days after operation, performed when the animal was 11 days old). *C*, marked temporary interference with the blood supply to the head of the right femur four days after operation, performed when the animal was 21 days old (surfaces made by cutting after decalcification). *D*, periosteal collateral circulation to the head of the right femur seventy days after operation, performed when the animal was 10 days old.

Ligation or Evulsion of the Principal Nutrient Artery to the Shaft.—The only significant changes in the femur occurred in rabbits a few days old. Because of diminished ossification in the proximal metaphysis, the epiphyseal cartilage tissue

of the head was slightly wider than that of the control a few days after operation. Tissue from the heads of the femurs that had been operated on contained as much india ink or lithium carmine as that from the controls after intravenous injections had been given.

Interruption of the Vessel That Passes Through the Trochanteric Notch.—No noteworthy changes occurred in the head of the femur when this branch of the deep femoral artery was ligated or evulsed. Changes suggesting a slight nutritional disturbance occasionally were noted in the proximal metaphysis of the shaft. They were more marked in the metaphysis when both the vessel that

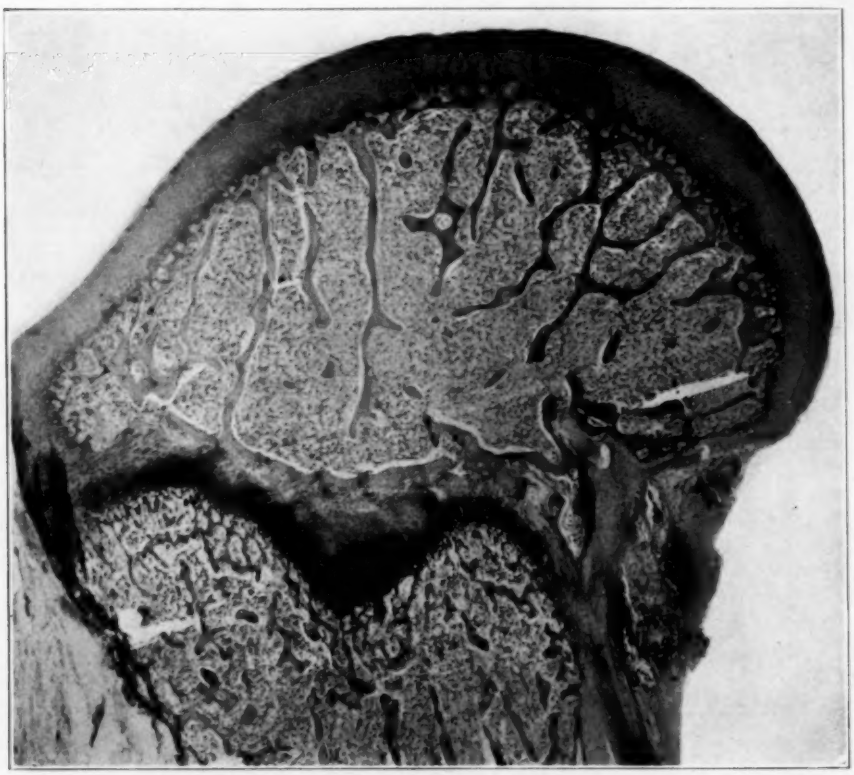

Fig. 2.—Microscopic appearance of the right femur (fig. 1 *D*), demonstrating the periosteal collateral circulation to the head after division of the ligamentum teres.

passes through the notch and the principal nutrient artery to the shaft were interrupted, but even these procedures caused no disturbance in the head of the femur.

Division of the Ligamentum Teres.—In young growing rabbits division of the ligamentum teres produced fairly uniform gross structural changes, most marked from ten to twenty days after operation (figs. 1 and 2). The head of the femur was broader and flatter, so that the margin overhung the neck and the stump of the ligament was depressed. The corresponding acetabulum was wider and shallower so as to accommodate the head, the articular surface being as much

as 60 per cent larger than that of the control. A slight to moderate anterior rotation of the head turned the shaft inward; occasionally the neck was short, because of a decreased proliferation of cartilage in the epiphyseal plate and a consequent diminution in growth. At the margin where the joint capsule is attached to the head the tissues were hyperemic, especially in the medial and posterior portions. There were no noteworthy alterations of the head in a few adult rabbits. In two of the twenty-five rabbits in this series, ranging in age from 12 hours to maturity, the head of the femur separated from the neck at the epiphyseal line and liquefied within the joint space. These femurs may have been infected. When india ink or lithium carmine was injected intravenously into growing rabbits, less material was present in the head in animals in which the round ligament had been cut than in the controls.

The microscopic changes in the head when there was no ligamentous attachment were essentially those usually caused by a mild nutritional disturbance and were mainly located about the fovea centralis. The amount of spongy bone decreased and that of osteoid tissue increased in the ossification centers in rabbits a few days of age; the fibrillar stroma of the medullary tissues was denser, and the number of cellular elements was diminished. There were a few small foci of necrosis. Sometimes the epiphyseal cartilage was narrowed because of a diminished proliferation of cartilage, and the vessels to the capsule entering the periphery of the head, where the articular and the epiphyseal cartilage unite, were dilated for collateral circulation. No collateral circulation developed from the tissues of the diaphysis through the cartilage plate. Marked necrosis in the tissues of the head was present after the ligamentum teres had been cut and a suspension of particulate charcoal had been injected through the deep femoral artery, which is the main blood supply to the tissues about the neck of the femur in the rabbit. The normal femur of a fetus or rabbit up to a few days of age had small vessels in the cartilage of the head which passed upward from the margin of the epiphysis and downward from the fovea toward the region where the secondary ossifying center forms or to the small center already present.

Division of the Ligamentum Teres and Interruption of the Vessel That Passes Through the Trochanteric Notch; Division of the Ligamentum Teres and Ligation or Evulsion of the Principal Nutrient Artery to the Shaft, and Division of the Ligamentum Teres, Interruption of the Vessel That Passes Through the Trochanteric Notch and Ligation or Evulsion of the Principal Nutrient Artery to the Shaft.—The changes in the head of the femur resembled those caused by cutting the ligament. They occurred only in growing rabbits, the extent of the alteration being inversely proportional to the age of the animal. The epiphyseal cartilage of the head was not widened, as it was when the principal artery to the shaft and the trochanteric vessel were destroyed but the ligamentum teres was left intact. This indicates that the blood supply to the ligamentum teres is important for proliferation of cartilage in the proximal epiphysis.

Ligation (Black Silk) of the Neck of the Femur (figs. 3 and 4).—Rabbits 30 days old had no gross deformity of the head of the femur after intracapsular ligation of the neck. The round ligament was large, and the haversian gland tissue of the acetabulum was hyperemic. Vascular granulation tissue covered the silk ligature. A moderate amount of fibrous tissue replaced the marrow, especially in the periphery; the amount of osteoid tissue was increased, in some instances spicules being parallel to the articulating surface, like a line of arrested growth. The attachment of the ligamentum teres contained many vessels larger than those of the control femur. Enlarged vessels also entered the head from the vascular tissues formed about the neck at its junction with the head.

Black silk tied about the neck of the femur of rabbits about 4 days of age usually produced complete necrosis and separation of the head. The separated head of one of these, examined thirty-four days after operation, was attached to the ligamentum teres, which protruded from a small and narrow acetabulum. This head, smaller than that of the control femur, contained a definite ossification center.

Division of the Ligamentum Teres and Ligation (Black Silk) of the Neck of the Femur (figs. 5 to 7).—The ligamentum teres was cut, and one or more loops

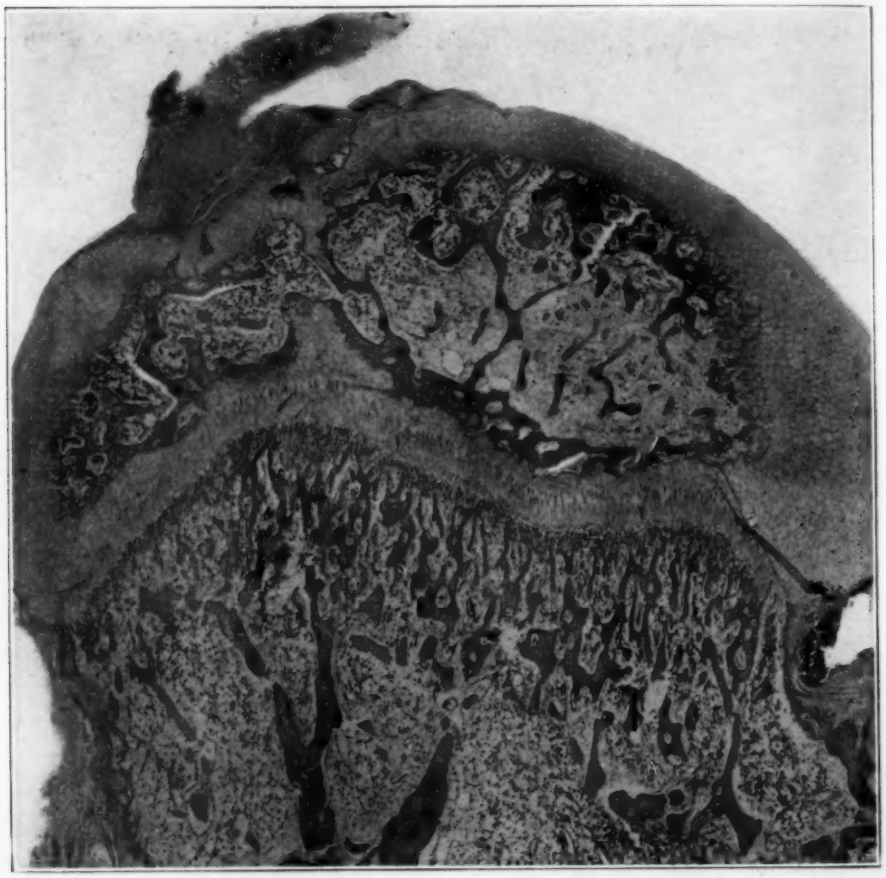

Fig. 3.—Partial necrosis, showing the line of arrested growth and fibrous tissue reaction in the head of the femur (× 16) thirty-six days after intracapsular ligation of the neck, performed when the animal was 31 days old. Many large blood vessels enter the head from the ligamentum teres and the vascular periosteal granulation tissue but none from the marrow of the shaft through the epiphyseal plate.

of silk were tied tightly about the neck of the femur inside the capsule and close under the peripheral edge of the proximal epiphysis. Changes in the head in growing rabbits in this group were considerably more marked than those following one or the other operative manipulation alone. In three of the eight animals

the head separated entirely from the neck of the femur through the epiphyseal line and partially or completely liquefied inside the joint capsule. The rabbits in which this occurred were 1½, 4 and 31 days old at the time of operation. The remaining five, from 12 hours to 34 days old, showed marked changes, consisting of decreased growth of the head, downward and forward displacement of the head, hypoplasia of the neck and marked proliferation of vascular granulation tissue from the neck to the lip of the head over the black silk ligature. The ligature on two femurs later was found to be loose, so that the periosteal blood supply to the head probably had not been stopped. The total length of the femurs

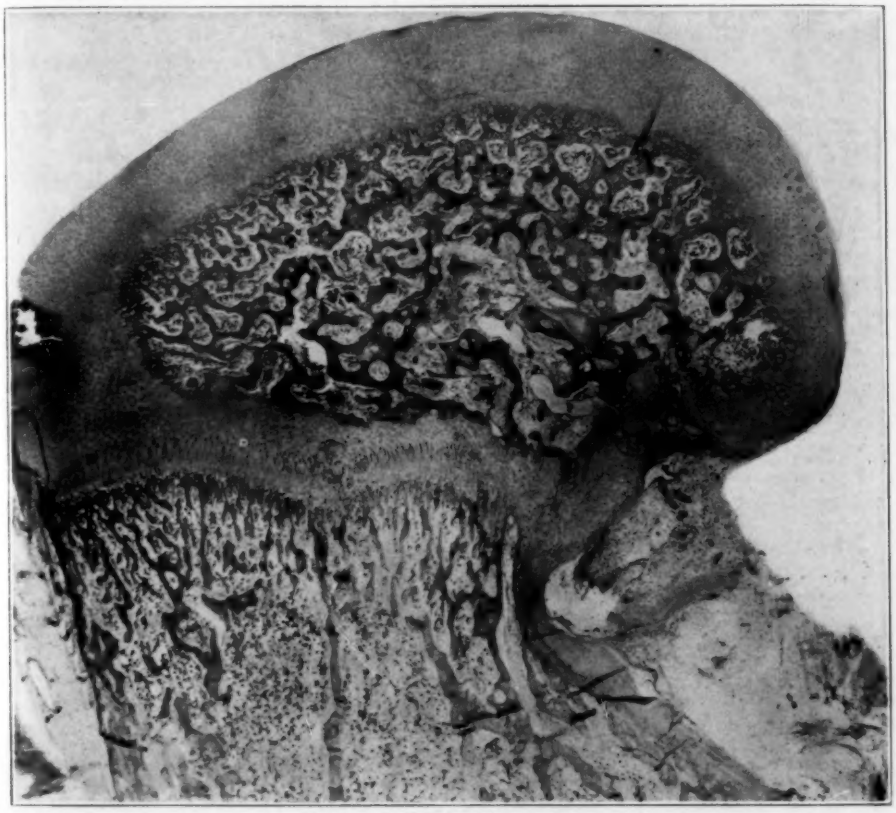

Fig. 4.—A section at a different level of the head shown in figure 3, illustrating revascularization from the collateral periosteal tissue that spans the space formerly occupied by the silk ligature.

that had been operated on equaled that of the controls, but the length below the base of the neck was less than that of the controls because of hypoplasia in the growth center of the metaphysis of the neck.

The head of the femur of one rabbit, operated on twelve hours after birth and examined thirty-five days later, was small and flat and was rotated about 60 degrees anteriorly on the shaft. It had no neck and was about 1 cm. below the base of the great trochanter. A shallow and narrow acetabulum articulated with the deformed head. The development of the acetabulum in these experiments seemed to depend on the size, growth, shape and contour of the articulating head.

The tissues of the head were necrotic, and in the animals that lived longest they were replaced by a creeping substitution of tissues from the periphery of the head, where collateral circulation had developed over the silk ligature about the neck. The necrosis included the epiphyseal cartilage, especially the center, but usually not the articular cartilage except the deeper portions. When separation of the epiphysis occurred, the narrow portion of cartilage plate adjacent to the region of growth in the metaphysis remained attached to the neck. The remaining portion of the plate separated with the head. The granulation tissue covering the silk ligature occasionally contained new periosteal bone and many blood vessels, which entered the shelving edge of the head. No noteworthy collateral circulation developed from the metaphysis through the cartilage plate to the head.

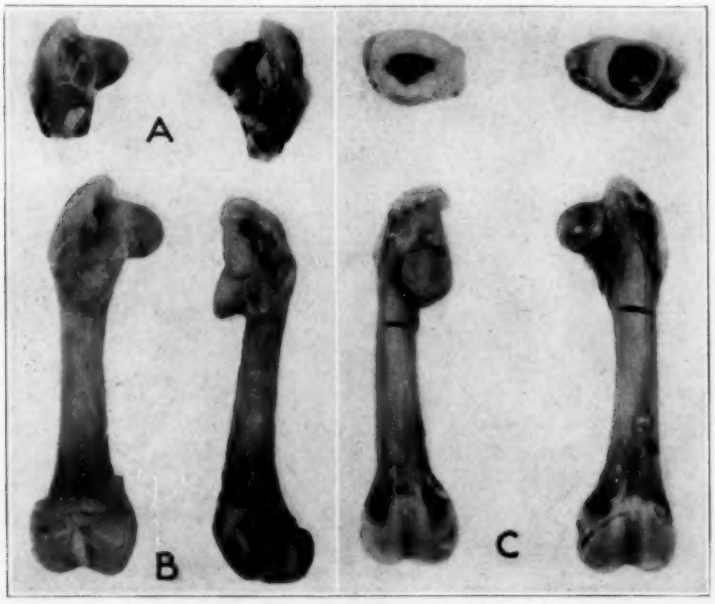

Fig. 5.—The femurs of rabbits after division of the right ligamentum teres and ligation of the neck. *A*, hypoplasia of the head and neck of the right femur with periosteal tissue for collateral blood supply to the head thirty-six days after operation, performed when the animal was 31 days old. *B* and *C*, marked hypoplasia of the head, neck and acetabulum and anterior rotation of the head, thirty-five days after operation, performed when the animal was 12 hours old.

Fracture of the Head of the Femur (figs. 8 to 10).—The head of the femur was cut from the neck and then fastened with a metal pin in its original position. In small animals the head was separated from the neck but not splinted. Owing to irregularities in the plane of the epiphyseal line, a portion of the head usually remained attached to the neck; sometimes parts of the epiphyseal line and tissues of the metaphysis were included with the fractured segment. When the head was held by a metal pin, it united quickly and firmly with the neck, and fifteen days after the operation only a linear scar remained at the fracture, surrounded

by a narrow zone of fibrous tissue. There was only slight deformity of the head, due to inaccurate alinement of the fractured segment. The size of the ossification center of the head was similar to that of the control femur, and the head occasionally contained fibrous tissue, indicating the presence of nutritional disturbance. In two cases union did not occur because fixation of the severed fragment was unsuccessful, but the head was as large as that of the control femur and consisted of normal tissue. Fixation by pin probably was insufficient to withstand the stress of weight bearing. The round ligament was larger and more hyperemic than that of the control, and the haversian gland of the acetabulum had more vascular fat tissue.

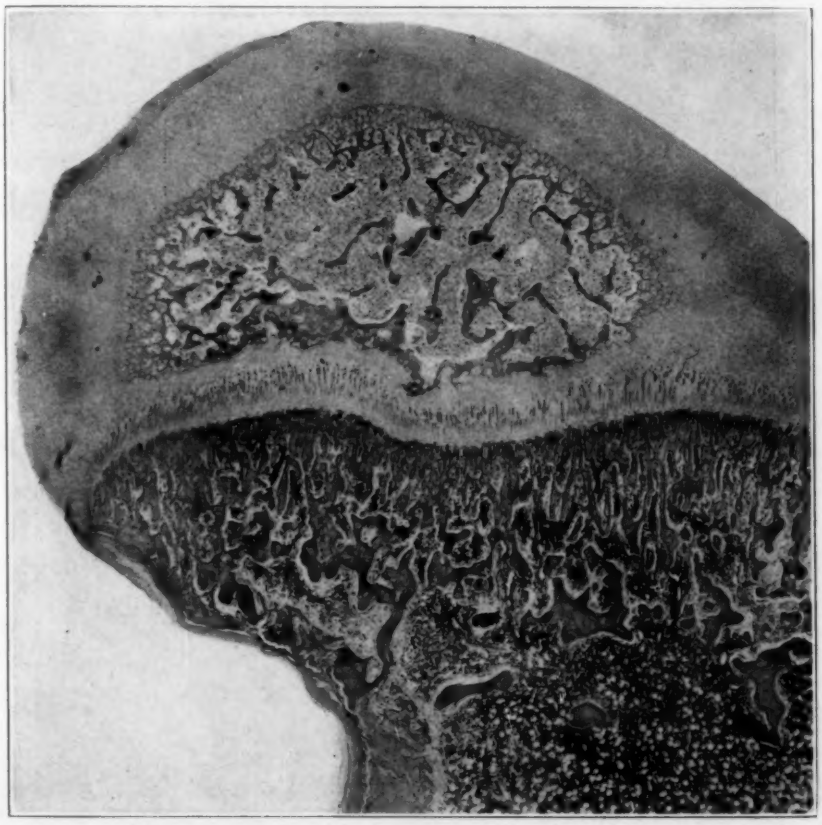

Fig. 6.—The head of the right femur (× 16) shown in figure 5 *A*. Necrosis of the tissues is marked, and the small ossification center has a wide layer of articular cartilage and osteoid tissue. No blood vessels enter the head from the metaphysis of the short neck.

When the fracture of the head was sufficiently far above the epiphyseal line to leave an intact layer of epiphyseal tissue, there was partial necrosis, and healing was delayed, particularly in the central portion, owing to the distance from periosteal blood supply and to the absence of collateral circulation through the cartilage plate from the shaft. Occasionally a portion of the neck and the epiphyseal cartilage plate was included in the segment. In these cases the tissues of the

neck and the metaphyseal margin of the cartilage plate became necrotic; the body of the cartilage plate receiving its blood from the head remained viable, as well as the tissues of the epiphysis.

Fig. 7.—The proximal end of the right femur (× 10) shown in figure 5 *B* and *C*. The flat cartilage has a small ossification center, and the epiphyseal line is parallel to the shaft and perpendicular to the line beneath the great trochanter, owing to the usual growth of the shaft from the great trochanter.

When the head was fractured but was not fixed to the femur (rabbits from 12 hours to 5 days of age), it did not unite with the neck. The femur grew

more rapidly than did the control and occasionally contained small regions of necrosis. The ossifying center, however, was smaller, and the articular cartilage was much wider than in the control femur. The symmetry of the head was maintained, the articular surface was smooth, and the broken surface, even though made through a small ossification center, usually became covered by a narrow, smooth layer of hyaline cartilage. The growth of the small acetabulum was not commensurate with that of the ununited head, and the acetabulum remained as a little shallow depression from which the head was forced into the joint space by its own growth. Marked hyperemia and an increase in the amount of fibrous connective tissue of the ligamentum teres and haversian gland tissue were noted.

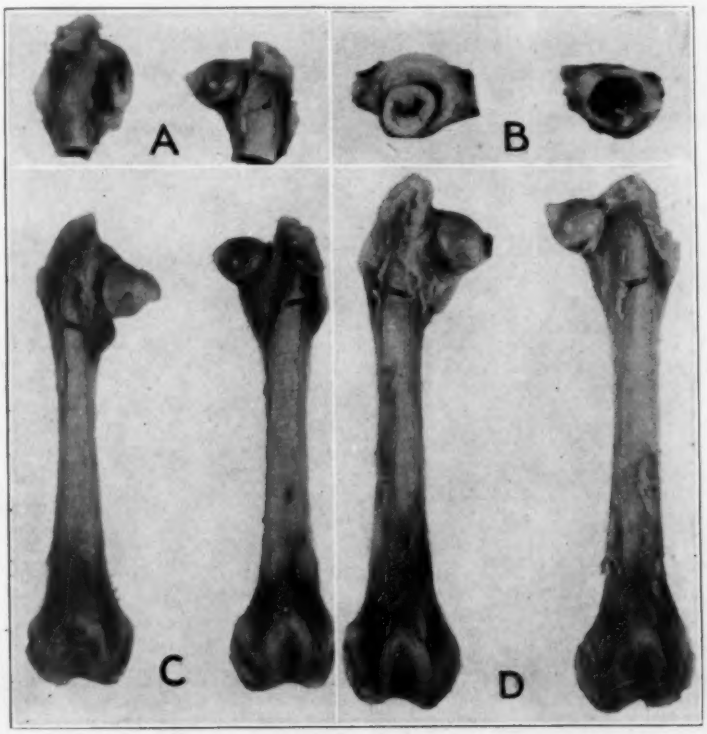

Fig. 8.—The head of the right femur was fractured inside the capsule of the hip joint, and in *C* and *D* it was splinted by metal pins. *A* and *B*, nonunion of the head thirty-five days after operation, performed when the animal was 12 hours old. The head developed as usual when attached only by the ligamentum teres, but the acetabulum remained narrow and shallow. *C* and *D*, firm union of the head of the right femur forty-five days after operation, performed when the animal was 30 days old. The round ligament is large and vascular.

Division of the Ligamentum Teres and Fracture of the Head of the Femur (figs. 11 and 12).—In these experiments the ligamentum teres was cut, and the head was fractured and, where possible, was splinted with a pin. The ligamentum teres was large, hyperemic and reunited to the fovea in three of eight rabbits with pin splints. In each case the fragment of the head of the femur united with

the neck, whereas healing occurred in only one of the five other animals in which the round ligament did not reunite. The neck of the femur in which the fracture healed without a ligamentous blood supply had been ligated so that nutrition to the tissues of the head attached to the neck was further disturbed. This marked disturbance of circulation had been compensated by collateral circulation to the tissues of the head from the shaft through the epiphyseal line. In this group of experiments no other collateral circulation developed to the head from the diaphysis through the epiphyseal plate.

The tissues of the united fragment were replaced by creeping substitution of new vascular connective tissue from the fovea (the ligamentum teres had reunited)

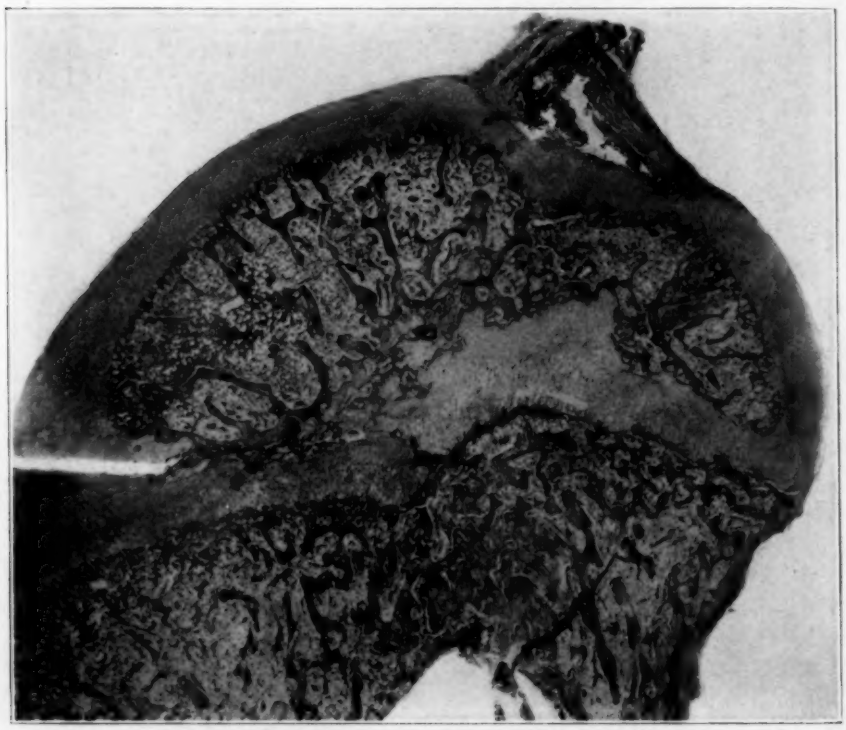

Fig. 9.—Revascularization and creeping substitution of the tissues of the head from the fovea centralis thirty-three days after intracapsular fracture and splinting of the head with a metal pin when the animal was 10 days old. There is good union of the fractured segment with little distortion of the epiphyseal line; × 16.

and from the periphery of the neck (the blood supply from the capsule). Ultimately new bone replaced the necrotic tissue. In these cases the head was smaller than that of the controls, but from eleven to forty-four days after operation it was the same size or slightly larger than at the time of operation. Moderate flattening and anterior rotation of the head were noted, but there was no dislocation or abnormality of the acetabulum. The haversian gland tissue was hyperemic. When the fragments of the head did not unite after fixation, it became necrotic and ultimately liquefied within the joint space. The fracture surfaces of the neck

were covered by a layer of cartilage in which new secondary ossifying centers occasionally developed from the tissues of the head which remained attached to the epiphyseal line at the time of fracture. In most cases the cartilage plate was narrower because of the diminished blood supply, and the neck of the femur was usually short. The hypoplasia of the neck seemed great because of the downward displacement on the shaft, since growth had continued as usual in the metaphysis beneath the great trochanter.

Fig. 10.—The head of the right femur (× 16) shown in figure 8*C*. Growth within the metaphysis has been restored, and the head is united completely despite poor alinement.

The head was completely freed from the right femur in five rabbits from 1½ to 5 days old, but it was too small for fixation. The fragments within the joint spaces were found later to be attached by fibrous tissue to the synovia or to the scar tissue about the joint capsule; one, however, had been displaced or liquefied. So far as could be determined, there was no growth of the ossification center in these fragments even forty-one days after operation. Usually new secondary ossification centers developed in the cartilage tissues of the head attached to the neck, but these were distorted and associated with considerable deformity and hypoplasia of the neck. The growth of the shaft from the metaphysis beneath the

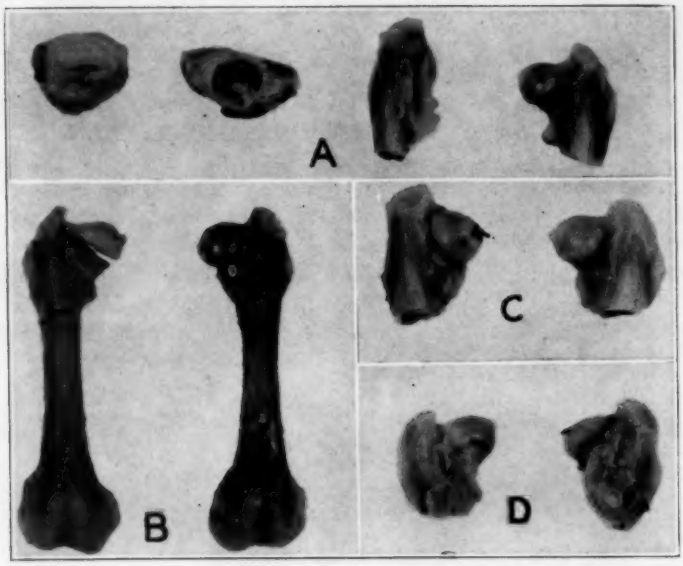

Fig. 11.—Femurs of rabbits after division of the right ligamenutm teres and intracapsular fracture of the head. *A*, hypoplasia of the right acetabulum and neck forty-one days after operation, performed when the animal was 36 hours old. The fragment of the head liquefied within the joint space. *B*, necrosis of the head of the right femur and nonunion of the splinted fragment seven days after operation, performed when the animal was 32 days old. Repair of these fractures occurred rarely, except when the ligamentum teres reunited with the fovea centralis. *C* and *D*, ligation of the neck in addition to the aforementioned procedures. Periosteal collateral circulation is abundant, and union of the small depressed fragment of the head is firm (see also figure 12).

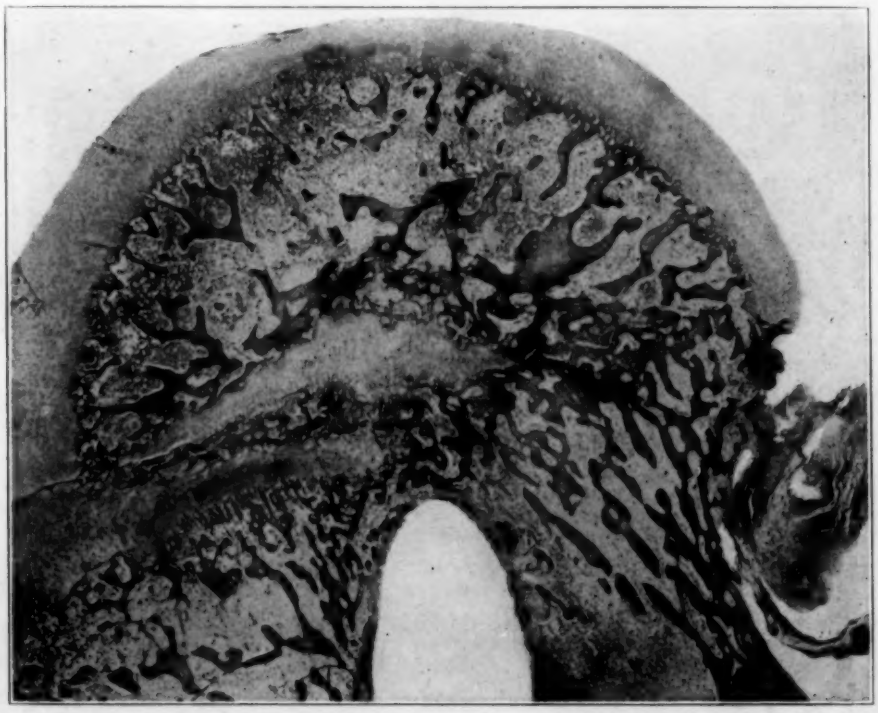

Fig. 12.—The head of the right femur (× 16) shown in figure 11 *C* and *D*. The necrotic tissues of the head are being revascularized and replaced by creeping substitution from the periosteum of the neck and medullary tissues of the shaft. Collateral circulation from the diaphysis to the head developed rarely and only after extensive interference with the blood supply to the head.

great trochanter was undisturbed. In one rabbit the ligamentum teres had become attached to new cartilage formed over the fracture surface of the neck.

There was also a marked tendency for the ligamentum teres to reunite in a group of rabbits in which a deep wound was made in the head of the femur without complete fracture. The necrosis produced was more marked, and healing was slower in these than in the control animals in which the ligamentum teres remained intact.

COMMENT

These studies of the effects of interference with the circulation of the femur in young rabbits emphasize the importance of several sources of blood for normal growth of the head and for the repair of injuries. Interference with circulation to the tissues of the shaft does not affect the head of the femur. The intervening septal plate of cartilage often is wider than usual, and the length of the neck of the femur is shorter because growth within the metaphysis has been disturbed. This indicates that the blood supply for cartilage proliferation in an epiphyseal plate is obtained from the corresponding epiphysis and that production of bone in the adjacent growth center depends on the circulation from the shaft. There are no appreciable vascular connections between the marrow tissue on the two sides of the plate. Osteogenic buds extend into the cartilage of the head in new-born and very young rabbits, but their connections with the metaphysis disappear soon after the formation of a secondary ossification center and an epiphyseal plate. In one rabbit collateral circulation developed through the plate to the tissues of the head after interference with the blood supply from the periosteum and the ligamentum teres. As noted previously, the epiphyseal cartilage after disturbance to the growth centers tends to disappear earlier than in the control bones. When the segment of the head of a fractured femur contains tissue from the neck and the ligamentum teres is uninjured, the osteoid structures of the neck attached to the segment become necrotic; so, also, but less marked, is the case of the tissues of the head remaining attached to the neck. Such changes indicate that the epiphyseal plate is not traversed by blood vessels.

The changes in the head of the femur of young growing rabbits following interruption of the ligamentum teres suggest that this ligament normally supplies part of the circulation to the head, particularly the tissues about the fovea centralis. This injury produces only a slight deformity of the head. When the periosteal blood supply to the head is destroyed, nutritional changes occur, especially in the peripheral tissues of this epiphysis. The disturbance in nutrition produced by the interruption of either of these sources of blood is temporary, for the other compensates and is adequate for the development of the head. This is demonstrated by hypertrophy and hyperemia of the ligamentum teres when the only source of blood is through this structure and by the growth of vascular granulation tissues about the lip of the head when the ligamentum teres has been cut. When both the periosteal and

the ligamentous blood supply have been interrupted, the tissues of the ligamentum teres attempt to reestablish continuity.

A fractured head separated from its attachments, in both adult and growing animals, may be revascularized and repaired by creeping substitution. This demands close approximation, good fixation of the fractured surfaces and, in growing animals, an adequate periosteal blood supply or reunion of the ligamentum teres. In adult animals the situation is slightly different, for there is no epiphyseal cartilage to act as a barrier to circulation between the medullary tissues of the shaft and of the head of the femur. Union of a fracture is impeded also when the periosteal blood supply is disturbed, although the ligamentum teres tissues are intact.

When the head is fractured in rabbits too small to permit fixation, the fragment grows and within a few days usually is larger than the control head. This increase in size seems due to the production of more articular cartilage, for the ossification center is no larger and frequently is slightly smaller than the center in the control. Absence of weight bearing on the head and the ability of articular cartilage to obtain nutrition from synovial fluid may explain this increase in the amount of cartilage. In rabbits only a few days old the blood supply from the periosteum seems relatively more important to the head of the femur than that through the ligamentum teres. The presence of more vessels of macroscopic size entering the periphery of the cartilage in the head than in the attachment of the ligament in young rabbits supports this view. The vascular connections with the fovea are established more slowly. The osteogenic buds for secondary ossification centers perhaps have a transient blood supply from the shaft through the epiphyseal cartilage.

These experiments are not concerned with the presence or absence of epiphyseal end-capillaries. They do, however, demonstrate that the larger medullary vessels from various external sources anastomose in the deeper tissues, so that if end-capillaries are present beneath the articular cartilage they do not depend necessarily on a particular source of blood.

The deformities of the femur produced in these experiments were caused by injury to the bone tissues and subsequent molding according to the stress of weight bearing and muscle tension. Possibly the loss of support by the ligamentum teres added to the distortion, although dislocation was rare and, when present, was attributed to the trauma of manipulation and injury to the joint capsule. The head was sometimes flattened over the neck, much as in the epiphysitis of the head of the femur which Legg, Perthes and Calvé described. The tendency to anterior rotation results from an adjustment to the lines of force in weight bearing, from a predominance of the internal over the external rotator muscles or from both. Internal rotation of the femur and consequent outward protrusion of the lower portion of the leg and foot

without noteworthy deformity of the head were noted in two control rabbits in which the short rotator muscle tendons were cut.

When the proliferation of epiphyseal cartilage for growth in the metaphysis of the neck was lessened, the neck was often short and at a decreased angle to the shaft (coxa vara). This hypoplasia of the neck was marked, especially in very young animals, so that often the length of the shaft from the base of the neck was considerably shorter than that in the control femur. The great trochanteric portion of the proximal epiphyseal plate was in the usual plane, transverse to the axis of the shaft, whereas the neck portion of the plate was more nearly parallel to the shaft and was elongated, as growth had proceeded in the usual way in the metaphysis beneath the great trochanter.

The large size of the head that had been fractured from the neck but not splinted was due to the increased growth of articular cartilage about the normal ossification centers. This acceleration of growth occurred because the separated fragment of the head carried no weight and was not confined within the acetabulum. It did not occur when the head was fixed to the neck after being fractured. When the fractured head of the femur, not splinted, continued to grow, it was not confined within the acetabulum, even though it was attached by the ligamentum teres, and the acetabular structure did not increase in size. Apparently the ligamentum teres alone was not sufficient to hold the head within the space during growth. This and the rarity of dislocation of the head of the femur following interruption of the round ligament indicate that this band of fibrous tissue is of little importance as a ligament.

The ability of joint tissues to reform articulating surfaces and to restore function completely is remarkable even in the case of marked injury and distortion of the bony parts, such as removal of the head of the femur. The reconstruction of the joint in these experiments was by growth of cartilage over the osteoid surfaces of the neck bared by the fracture and by the articulation of this new cartilage surface with similar new or old cartilage in or about the acetabulum. When necessary to support weight and to hold together articulating surfaces, fibrous tissue proliferated within the capsule. Small secondary centers of ossification often developed in the portion of head remaining on the neck when sufficient collateral circulation had been established. In one rabbit a few days old, after complete isolation of the head of the femur, the ligamentum teres became attached to the articular surface over such a new ossification center.

Results obtained in these experiments apply to young growing animals but not to adults. In the latter the bones are fully formed, they contain a relatively greater amount of osseous supporting tissue and there is medullary continuity of the epiphyses and the diaphysis. All the results cannot be transferred even to older growing rabbits, since the

epiphyses have attained more nearly full development. Some of the principles, however, such as regard necrosis and repair in an isolated fragment, and the general plan for collateral circulation should apply to all groups. The blood supply through the ligamentum teres in adult rabbits may not be sufficient to prevent complete necrosis of a fractured segment, but certainly it is important as a potential source when collateral circulation is needed. Other things being equal, an intracapsular fracture of an adult femur should heal more readily than that of a growing bone, since the medullary circulation is continuous throughout the bone after cessation of growth in length.

Traumatic injury to the tissues may have added to the circulatory disturbances produced in the femurs of these rabbits, but opening the hip joint and manipulating the bones alone produced no appreciable changes.

SUMMARY

The most important source of blood to the head of the femur in growing rabbits is through the small vessels entering this epiphysis from the periosteum where the capsule of the hip joint is attached at the margin of the articular cartilage. The ligamentum teres also contributes blood to the head, particularly to the tissues about the fovea centralis. If the blood supply to the capsule or to the ligamentum teres is interrupted, the remaining source will compensate for the loss and be adequate for repair of injury, for growth and for function of the part. Interference with nutrition of the metaphysis of the neck of the femur does not affect the tissues of the head, except by widening the intervening septal plate as a result of diminished ossification of cartilage.

There is no noteworthy vascular connection between the medullary tissues of the shaft and the head through the intervening cartilage plate. Collateral circulation rarely develops through the plate, and then only after marked vascular disturbance to the head of the femur. Proliferation of cartilage in an epiphyseal plate depends on the circulation of the epiphysis, and the blood to the metaphyseal growth regions is supplied by the shaft. Separation of the head of the femur occurs through the cartilage line in the plane between the limits of the epiphyseal and the metaphyseal circulation.

The repair of an intracapsular fracture through the head of the femur in growing rabbits is retarded if either of the two principal sources of blood to the head is interrupted. Interference with the ligamentum teres and complete intracapsular fracture of the head produce marked necrosis of the loose fragment, which may be revascularized and replaced by new bone if it is fixed in apposition with the fracture surface of the neck. This creeping substitution proceeds from the vascular granulation tissue at the periphery of the neck where the joint capsule is attached.

Vascular disturbance to the head of the femur accentuates the remaining possible sources of blood. The severed ligamentum teres tends to reunite with the fovea when the capsular supply also is interrupted. In the experiments one ligament became attached to the new cartilage formed over the fracture surface of the neck. Beneath this new articular cartilage was a small new secondary ossifying center.

Not only will the head of the femur in young rabbits continue to grow when attached only by the ligamentum teres, but in a few days it may become larger than the control head. This increase in size is due to the increase in the amount of cartilage, probably because the part has no weight-bearing function. The development of the acetabulum depends on the integrity and growth of the head of the articulating femur.

Deformities of the head and neck of the femur in young rabbits resulting from nutritional disturbances of the head vary according to the extent of the injury, the mechanical stress of weight bearing (flattening of the head and coxa vara), the muscle pull (anterior rotation) and the inhibition of growth in the metaphysis of the neck. Other things being equal, the degree of deformity is inversely proportional to the amount of osseous supporting tissue present, which depends on the age of the animal. The blood supply to the head must be adequate for the proliferation of cartilage in the epiphyseal plate in order to obtain normal growth and development of the proximal end of the femur. Hypoplasia in the metaphysis of the neck results in a diminution in the growth of that portion of the femur between the lower epiphysis and the base of the neck, while the total length of the bone is the same as that of the control, owing to growth, as usual, in the metaphysis of the great trochanter.

Disturbances of the external sources of blood and trauma to the head of the femur in adult rabbits probably do not cause all the changes noted in growing rabbits. Obliteration of the proximal epiphyseal cartilage plate when growth in length ceases establishes diaphyseal circulation to the head and makes other sources of blood less significant. This probably accounts for the dearth of blood vessels in the round ligament in adults. The potential sources of blood to a fragment of a fractured head of an adult femur, however, are the same as those in growing bone; if the ligamentum teres provides sufficient blood for viability of the fragment, it should unite more readily than in the growing femur, because of the supply of diaphyseal blood to the fracture of the neck.

The extent to which these observations on rabbits may be transferred to man is questionable, but certainly the underlying principles are important for understanding of disease and trauma of the head of the femur.

TRAUMATIC ARTERIOVENOUS FISTULA INVOLVING THE RIGHT FEMORAL ARTERY AND VEIN

SPONTANEOUS CLOSURE

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An arteriovenous fistula seldom becomes closed without surgical intervention. In the following case spontaneous closure occurred.

REPORT OF A CASE

A man 44 years of age recently was seen at the clinic. He had an arteriovenous aneurysm of the right femoral artery and vein, but this condition was not his reason for seeking medical aid. In fact, the arteriovenous fistula had closed spontaneously about seven years before. The end-result was identical with that which would have followed ligation of the artery and the vein.

The patient had first registered at the clinic in 1924, because of the presence of a swelling in the right thigh, which emitted a bruit and gave the sensation of a purring cat to the palpating hand. For some reason he did not wait for an appointment but left Rochester before physical examination or any laboratory studies had been carried out.

The patient was brought to the clinic by his relatives in August 1935, because of dementia paralytica.

At the age of 11 years the patient received a bullet wound in the right thigh. An arteriovenous fistula (fig. 1) developed at the site of the wound. The usual train of events under these circumstances ensued, namely, the development of varicosities and associated swelling of the limb. He had worn an elastic bandage for twenty years. He had been aware of an inequality in the length of the legs and had had the heel of the left shoe built up, so as to facilitate walking. A bruit and thrill had been present until seven years before his last registration at the clinic.

Physical examination revealed conditions associated with syphilitic infection of the central nervous system, which require no further comment. There was a swelling in the right thigh, measuring 6 by 8 cm., which represented the thrombosed aneurysmal sac. At this time the signs of arteriovenous communication could no longer be elicited. The right tibia was 4 cm. longer than the left (fig. 2); the femurs were of equal length (fig. 3). There was an unusually strong pulsation in the right femoral artery, but the right popliteal, right dorsalis pedis and right posterior tibial arteries could not be palpated. Despite this condition the circulation in the right limb was adequate; blanching was minimal when the leg was elevated, and the blood returned promptly when the limb was lowered. There was no history of claudication.

From the Division of Medicine, the Mayo Clinic.

Fig. 1.—Arteriogram showing the femoral artery, with interruption between points *a* and *b*.

Figure 2

Figure 3

Fig. 2.—The right leg is thicker and longer than the normal left leg.
Fig. 3.—The right leg is longer than the left; the thighs are the same length.

An arteriogram of the right femoral artery was made by injecting into it 40 cc. of colloidal thorium dioxide. As previously described,[1] the artery was closed by digital pressure just proximal to the site of injection, and closure was maintained while a series of roentgenograms was made as quickly as possible. In the course of this procedure an unusually strong pulsation was noted in the femoral artery. Figure 1 illustrates the interruption of the femoral artery at the site of the thrombosed aneurysmal sac. Cardiac hypertrophy was not present, and physical examination did not reveal any other abnormality.

The oxygen content of the blood which was obtained from the right femoral vein was 12.7 volumes per cent, and the oxygen capacity was 19.5 volumes per cent. The oxygen saturation, which is obtained by dividing the oxygen content by the oxygen capacity, was 65.1 per cent, indicating that there was no mixing of venous with arterial blood and that closure of the fistulous communication was complete.

COMMENT

While it is possible for a recently acquired arteriovenous fistula to heal spontaneously,[2] we were unable to find any reference in the literature to an occurrence similar to the one that we are reporting. In fact, a survey of the pathologic physiology of such a fistulous communication affords the explanation for the extreme rarity of such a possibility and the explanation for the usual course of progression unless surgical intervention is resorted to. Since the pressure in the venous channels is considerably lower than that in the capillary bed, the blood follows the path of least resistance and causes a progressive dilatation of the involved vein and its tributaries. This condition produces changes in the venous walls, which have been described as "arterialization," as well as subsequent changes commonly encountered under these circumstances. If the arteriovenous communication is large, a considerable amount of blood will be shunted away from the general circulation, and presently there will occur a corresponding dilatation of the artery and vein proximal to the fistula. In the present case the artery proximal to the fistula was unusually large, and there can be little doubt that the fistulous communication must have been rather large before its closure. Ordinarily, as Holman[3] showed, "this dilatation is progressive and will continue until the resistance offered by the fistula plus the resistance to any further dilatation of the vessel leading to it equal the resistance which exists in the capillary bed elsewhere." The result of diverting a goodly proportion of arterial blood from the natural channels is similar in its

1. Horton, B. T.: Arteriovenous Fistula Involving the Common Femoral Artery Identified by Arteriography, Am. J. M. Sc. **187**:649 (May) 1934.

2. Pemberton, J. deJ.: Arteriovenous Aneurysm, Arch. Surg. **16**:469 (Feb.) 1928.

3. Holman, Emile: Arteriovenous Aneurysm: Clinical Evidence Correlating Size of Fistula with Changes in the Heart and Proximal Vessels, Ann. Surg. **80**:801 (Dec.) 1924.

effect on the heart to an aortic regurgitation with resulting cardiac enlargement. We have, unfortunately, no information regarding the previous cardiac status of this patient, but during the seven years following the natural and yet unexplained closure of the arteriovenous fistula there could have been the same decrease in the size of the heart as has frequently been shown to occur after surgical obliteration of the abnormal communication.

The long duration of the fistula in itself is no explanation for the closure. In many of the cases reported in the literature,[4] arteriovenous fistulas in the same anatomic situation have been present for twenty-five years or more without coming to the same fortuitous termination. In other situations they have existed as long as fifty-five years, as in a case of aneurysm of the vessels of the wrist which was reported by Scottin;[5] therefore, the long duration in itself does not explain the natural cure.

The question may be raised as to the part the syphilitic infection played in the closure of the fistula. Regarding this, nothing can be stated with certainty, but the probability is that there was no relation.

Interestingly, many attempts have been made to close arteriovenous fistulas by nonsurgical means, such as injection of coagulating fluids, for instance, solution of ferric chloride, and the use of galvanopuncture.[4] Most of these efforts have resulted in failure, in secondary hemorrhage with gangrene, in loss of the limb or, in some instances, even in loss of life. Guattini,[6] in 1785, succeeded in curing a brachial aneurysm by a combination of direct pressure in the region of the fistulous communication and indirect pressure—or digital obliteration of the afferent artery. Vanzetti, Monteggio and Brambilla[7] are credited with similar cures, but these results were the exception rather than the rule, and even these conservative procedures were known to cause inflammatory changes about the sac and at times to result disastrously.

This case presents several other interesting features. First, despite the fact that the fistulous communication was in the upper part of the thigh, the increase in growth of bone was in the tibia rather than in the femur. An adequate explanation of this phenomenon cannot be given. Second, the actual occurrence of increase in length of the bone, although usually seen in the congenital form of arteriovenous fistula,[8] has rarely

4. Callander, C. L.: Study of Arteriovenous Fistula with an Analysis of Four Hundred and Forty-Seven Cases, Johns Hopkins Hosp. Rep. **19**:259, 1920.

5. Scottin, quoted by Callander.[4]

6. Guattini, quoted by Callander.[4]

7. Vanzetti, Monteggio and Brambilla, quoted by Callander.[4]

8. Horton, B. T.: Hemihypertrophy of Extremities Associated with Congenital Arteriovenous Fistula, J. A. M. A. **98**:373 (Jan. 30) 1932.

been reported in association with the acquired type. The fact that the fistula was established in early life is the explanation of this phenomenon.

SUMMARY

Our object in reporting a case of acquired arteriovenous fistula of the femoral artery and vein is to describe a unique circumstance: A condition which inherently has a natural trend of progression came to a spontaneous cure after being present for approximately twenty-five years, an event which, as far as we are able to ascertain, has never previously been recorded.

SURGICAL TREATMENT OF IDIOPATHIC HYPERTROPHY OF THE BREAST

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The majority of women with noninflammatory, nondegenerative and non-neoplastic hypertrophy of the breast complain of no symptoms apart from slight inconvenience occasioned by the enlarged glands and require no treatment. Frequently, however, the hypertrophy assumes such proportions as to cause physical, occupational or psychic embarrassment, and so becomes a condition demanding relief.

Logical treatment for this type of hypertrophy would be directed to removal of the stimulus toward abnormal growth, but since it is yet unknown, such treatment is unavailable. It is hoped that added interest and more careful study may reveal the underlying defect and thus lead to more rational therapeutics. Attempts to correct the condition by organotherapy, iodides, roentgen therapy, bandaging and a host of other measures have brought negligible results. When other treatment has failed and the symptoms justify the hazard of operation, plastic surgery offers a well defined technic for alleviating the hypertrophy.

Since Lexer's article published in 1923, plastic surgery of the breast has made tremendous progress. Although the end of the possibilities has not been reached, the present status of the procedure is sufficiently standardized to warrant operation with reasonable assurance that the surgeon will reduce the size of the breast, give it a normal configuration and location, transfer the nipple and areola to their proper place on the reduced breast and at the same time preserve the blood supply and disturb the function slightly, if at all.

In each particular instance the surgeon must critically study the indication to determine whether operative intervention is justified; he must be especially cautious in view of the fact that spontaneous regression is possible. The desirability of the reconstruction cannot be left entirely to the whim of the patient, despite the minor character of the operative procedure.

PRELIMINARY OBSERVATIONS

Anatomy of the Normal Breast.—Before describing the operative procedure, it is essential to refer briefly to the more salient anatomic features of the normal breast, since the aim of the technic is to reconstruct the hypertrophied breast and yet to preserve its blood supply and secretory function.

The breast is a hemispheric, racemose gland, protruding from the chest as a conical disk, enclosed in two layers of superficial fascia. The anterior layer sends trabeculae into the skin (ligaments of Cooper), which account for the firmness of the breast and the difficulty encountered in separating the skin from the gland. The posterior layer sends trabeculae into the deep fascia covering the pectoralis major muscle. This attachment is loose and permits free shifting of the breast on the chest wall. Between the posterior layer of the superficial fascia and the deep fascia covering the muscles of the chest is loose cellular space; it facilitates the separation of the gland from the underlying muscle.

Aside from the prolongations given off anteriorly to the skin and posteriorly to the pectoral fascia, the superficial fascia sends trabeculae

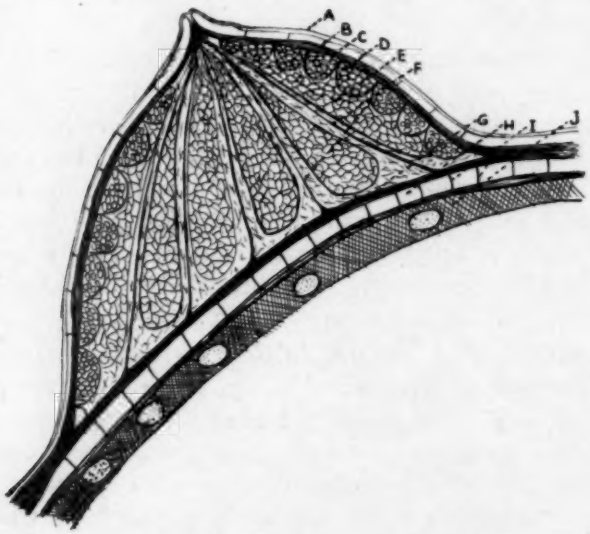

Fig. 1.—Sagittal section of breast. *A* indicates the skin; *B*, the ligament of Cooper; *C*, the superficial layer of superficial fascia; *D*, fatty tissue; *E*, glandular tissue; *F*, trabeculae; *G*, the deep layer of superficial fascia; *H*, cellular space; *I*, trabeculae; *J*, pectoralis major.

into the breast substance, which divide it into from twelve to fifteen wedge-shaped lobes, radiating from the nipple. Each lobe has a main duct opening on its summit. These lobes may be considered miniature mammary glands, each functionally and anatomically independent; thus a lobe can be removed without material interference with the function of the rest of the organ.

The entire breast is covered with a layer of fat of variable thickness; it invades the interlobular structures and disappears in and around the areola. It is this fatty tissue rather than the glandular tissue that determines the size of the breast (fig. 1).

The dimensions of the normal gland are variable, depending on age, race, climate and physiologic state. The average virginal mammary gland is from 10 to 15 cm. in diameter and weighs from 140 to 200 Gm. It projects from the chest wall 5.5 cm., at an angle of 30 degrees. At its summit it shows the areola to be 4 cm. in diameter, in the center of which is the nipple, 1 cm. in diameter, at an elevation from the areola of from 1 to 2 cm. The nipple is located over the fourth or fifth interspace, 12 cm. from the midline. It is composed of nonstriated, circular and longitudinal muscle, blood vessels and lactiferous ducts.

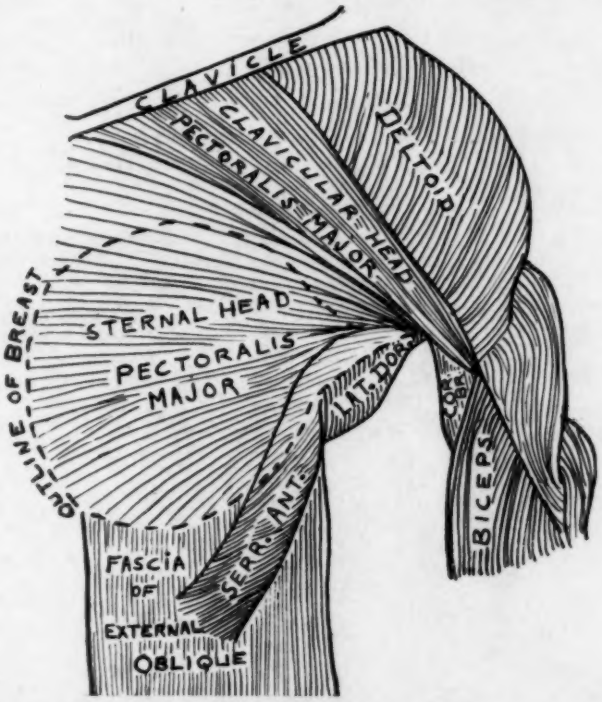

Fig. 2.—Extent of the breast on the chest wall.

The base of the breast is roughly hemispherical and extends into the axilla. The upper curve lies on the pectoralis major and serratus anticus muscles, two thirds of the gland resting on the former; the lower curve is situated on the obliquus internus and rectus abdominis muscles (fig. 2). The axillary tail lies on the serratus anticus and pectoralis major muscles and extends to the third rib in the axilla, gaining entrance into this space by an opening in the axillary fascia. This prolongation is the only part of the gland beneath the deep fascia; therefore, its enucleation is more difficult than that of the rest of the gland.

The extent of the breast is variable and is underestimated in the usual anatomic description. It extends from the second to the sixth

or seventh interspace vertically and from the middle of the sternum to the middle of the axilla horizontally. Each breast may be divided surgically into four quadrants by two oblique lines; the first starts from the sternum at the level of the third costal cartilage and runs downward and outward to the seventh rib in the midaxillary line; the second begins at the third rib at the anterior axillary fold and extends downward and inward to the sixth costal cartilage, at a point between the angle of the cartilage and the attachment to the sternum.

Blood Supply (fig. 3).—The principal arterial supply to the breast is obtained from the following vessels:

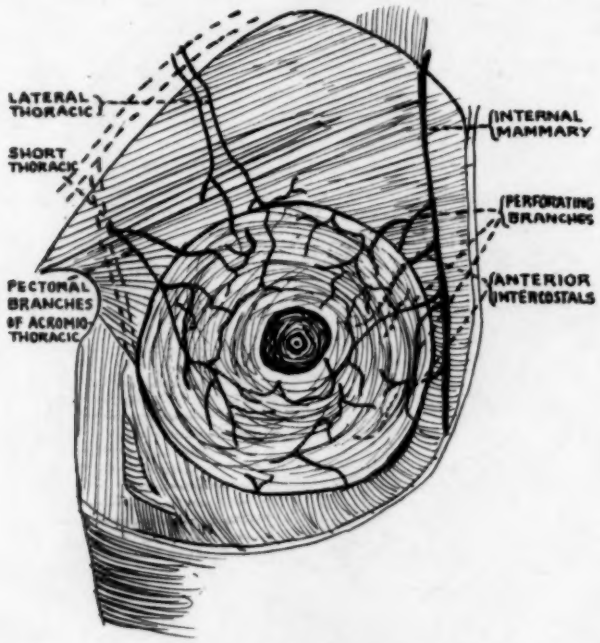

Fig. 3.—Blood supply of the breast.

1. The internal mammary artery, which gives off perforating branches, especially the second, third and fourth, and the anterior intercostal arteries. The former emerge from the intercostal space on each side of the sternum, pierce the pectoralis major muscle, turn outward and give off superficial branches, which supply the skin, superficial fascia and anterior surface of the breast. The deep branches supply the parenchyma and break up into a network around the areola. The anterior intercostal arteries lie between the deep layer of the superficial fascia and the deep fascia, enter the posterior surface of the gland and anastomose with the aortic intercostal arteries. These vessels form two plexuses: (*a*) a subareolar plexus, formed by superficial branches that

give off branches to the nipple, areola and adjacent parenchyma; (*b*) a deep plexus, composed of deep branches which emerge from the base of the organ and send branches to the parenchyma and stroma.

2. The lateral thoracic (long thoracic or deep external mammary) artery, which arises from the second part of the axillary artery, descends along the lateral border of the pectoralis minor muscle and anastomoses with the intercostal and subscapular arteries and with the pectoral branches of the thoraco-acromial artery, which supplies the upper lateral quadrant.

3. The short thoracic (superficial external mammary) artery, which is a branch of the third division of the axillary artery, or the first portion of the brachial artery, passes through the superficial fascia of the axilla, anastomosing with the long thoracic artery.

4. Pectoral branches from the acromiothoracic artery anastomose with the foregoing vessels to supply the supralateral quadrant.

The superficial veins form a circle around the base of the nipple (circulus venosus of Halle). From this anastomosing circle large branches run to the periphery of the gland and empty into the external jugular, axillary and internal mammary veins. The deep veins accompany the arteries.

Pathologic Process.—There are several varieties of idiopathic hypertrophy:

1. Congenital
2. Acquired
   - (*a*) Puberty (virginal, glandular, parenchymatous)
   - (*b*) Adult
     - (1) Hypertrophic (adipose pendulous)
       - (*a*) Fatty degeneration
       - (*b*) Fatty infiltration
     - (2) Atrophic (flabby pendulous)

The congenital type is rare and is considered to be a manifestation of precocious sexual development. Malleat described a case in which hypertrophy existed at birth and menstruation began at fifteen days after birth.

In the type that begins at puberty the breast continues to enlarge beyond normal limits. Dunston reported a case in which one breast weighed 64 pounds (29 Kg.). In Deaver and McFarland's collection of one hundred and eighty-two cases, the hypertrophy was bilateral in one hundred and forty-two instances and limited to one breast in forty.

The histologic changes are indefinite. Specimens sent to the laboratory reveal hyperplasia of the pericanalicular and periacinar fibrous stroma, with new formation of acini and ducts or fatty hyperplasia, with

little glandular tissue. Lewis stated the belief that gynecomastia, virginal hypertrophy and fibro-adenoma represent different phases of the same pathologic process and may have the same etiologic factor.

The adult type begins with pregnancy or lactation. It may be associated with generalized adiposity or be present as localized fatty infiltration or degeneration.

The atrophic form represents senile involution; the skin hangs on the chest wall like an empty sac, containing little or no breast tissue. This condition may be abnormal in the amount of tissue present or in the time of its appearance (premature).

Symptoms.—The enlargement occurs slowly, requiring from one to ten years for its full development. Early in the process there is no change in contour, and the hypertrophied organ differs from the normal breast only in size. There are no symptoms at this stage except those arising from the inconvenience of the enlargement. Later, when the increasing weight makes traction on the fixation apparatus, the skin, suspensory ligament and retromammary fascia give way, and a pedicle is created from which the hypertrophied breast hangs.

The subsequent symptoms are mainly mechanical. Striae appear, due to stretched and torn connective tissue. The skin of the areola becomes flattened and bluish. As a result of the mechanical disturbance of the circulation, edema develops, and veins are seen coursing beneath the skin. Maceration dermatoses appear in the submammary folds.

The patient complains of aching pains and inability to engage in occupations and sports, in which freedom of movement is essential. This situation leads to social maladjustment and depression, and the patient feels excluded from those phases of life which women anticipate with pleasure. In time she may present not only a surgical but an economic problem.

On physical examination the breast as a whole feels solid. The prolongations of connective tissue from the skin to the gland become tense and separate the fat into isolated nodules; this nodularity is palpable on the anterior surface, if the layer of fat permits. The nipple is flattened, is flush with the surface and at no time shows retraction. The posterior surface of the gland is never adherent to the pectoralis muscle.

Diagnosis.—Diagnosis is obvious, though mistakes have been made. The size and configuration of the breast are characteristic, and the absence of symptoms other than those attributable to great weight gives rise to little doubt as to the nature of the malady. A neoplastic hypertrophy shows definite features, such as irregularity of the shape of the breast, retraction of the skin and nipple, hard nodularity, fixation and metastasis. An inflammatory condition gives characteristic clinical signs.

The only difficulty in diagnosis is in differentiating the condition from generalized cystic degeneration, which gives rise to signs and symptoms identical with those of idiopathic hypertrophy. The distinguishing features may be so fine as to defy diagnosis. It is obvious that systemic involvement or obstruction to the circulation, such as that in elephantiasis, must be ruled out.

TECHNIC

Location of the New Areola.—To determine the location of the new nipple, a line is drawn from the center of the clavicle to the anterior superior spine of the ilium and another from the xiphoid process to the

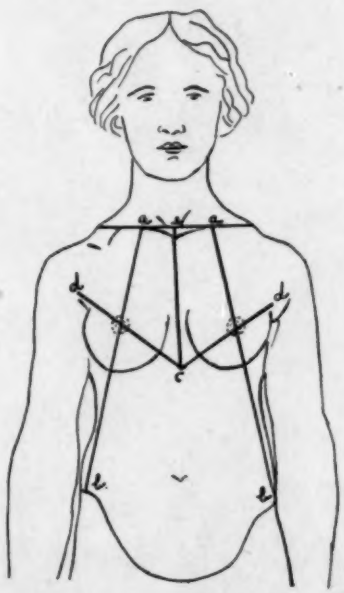

Fig. 4.—Location of the new areola (*a-b* indicates the line from the center of the clavicle to the anterior superior spine of the ilium; *c-d*, the line from the xiphoid to the anterior axillary web; *e-c*, the midsternal line).

anterior axillary web. The intersection of these lines is the approximate point for the location of the nipple. Similar lines are drawn on the opposite side, and a midsternal line is made for comparison between the two sides. The points thus determined are marked by a superficial scratch made with the point of a scalpel (fig. 4).

Approach to the Breast.—At the point thus indicated, a circle of skin and fascia, about 4 cm. in diameter, is excised to the fatty layer. From the inferior margin a vertical incision is carried just through the skin, as far as the dislocated areola. From this point the incision is continued around the circumference of the areola, enclosing an area equal in diameter to that of the aperture already prepared. A second

concentric incision is made outside the first at a distance of 2 cm. It is most important that these incisions should not extend deeper than the corium, in order to preserve the circulation.

The skin between the two circular incisions is carefully separated, in a manner similar to raising a full thickness skin graft. Beisenberger forcibly ablated the skin with a hemostat, baring a glistening, whitish corium (fig. 5*A*). The purpose of this careful dissection is to avoid damaging the superficial anterior areolar plexus of blood vessels and nerves. The areola remains attached to the breast only by fibers of

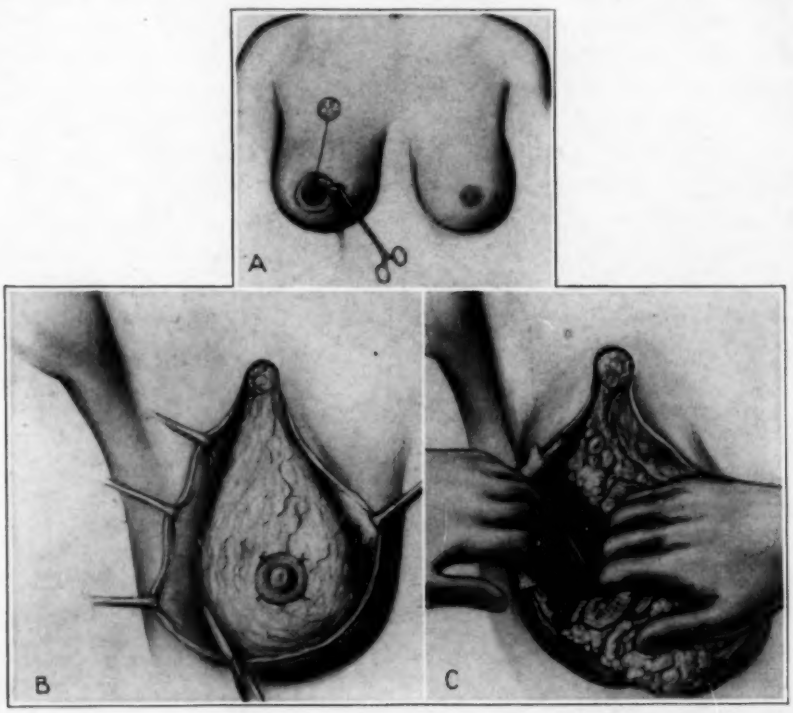

Fig. 5.—*A*, the aperture for the new areola; incision for exposure of the breast; circumareolar skin ablated with hemostat to preserve the areolar plexus. *B*, temporary sutures fixing the areola; skin dissection. *C*, enucleation of the breast.

connective tissue from the superficial fascia, blood vessels and lactiferous ducts. In order to prevent its being torn out or twisted inadvertently, the areola is fastened to the underlying tissues by four temporary silk sutures (fig. 5*B*).

The margin of the incision is everted with hooks, and the skin is separated from the superficial fascia by cutting the prolongations, which extend from the fascia to the skin (ligament of Cooper). Care must

be taken not to perforate the skin (fig. 5*B*). The dissection is continued until the skin adjacent to the incision has been separated for a distance of from 4 to 5 cm. The purpose of this superficial dissection is to preserve the venous circle at the summit of the breast. It is important that no further dissection be made on the medial side, which must serve as a pedicle for the breast in its new position and which carries the second, third and fourth perforating and intercostal branches of the internal mammary artery and the aortic posterior intercostal artery.

On the lateral side where the superficial fascia is attached to the skin, an incision is made through the fascia into the fatty layer covering the breast. The lateral tissues are retracted with the left hand; the right hand, protected by a pad of gauze, acts as a blunt dissector,

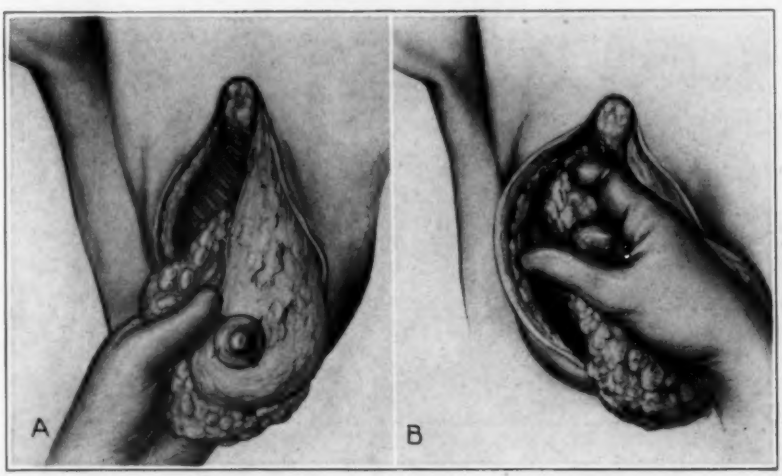

Fig. 6.—*A*, delivery of the breast, showing a wide medial pedicle. *B*, enucleation of the axillary prolongation.

separating the breast from the skin, to which a good layer of fat remains attached. The dissection is continued to the midaxillary fold and to the most dependent portions of the breast (fig. 5*C*).

So far there has been little bleeding, as the dissection has not been carried beyond the fatty layer and no important blood vessels have been encountered.

Delivery of the Breast.—By placing the hand in the retromammary space, the breast may be easily shelled out. The axillary border of the pectoralis major muscle is exposed, and it stands out prominently. A few restraining strands of connective tissue, passing from the breast to the deep fascia, may demand incision. Care should be taken to avoid cutting the medial perforating branches of the intercostal arteries (fig. 6*A*). Slight difficulty may be encountered in delivering the axillary

tail of the gland, since it lies beneath the deep fascia, which has to be cut. After division of the fascia, the finger is passed into the axillary space, and the axillary prolongation is enucleated (fig. 6*B*). The breast may be lifted entirely from its bed; it remains attached only at the sternal border by a pedicle from 4 to 5 inches (10 to 12.5 cm.) in width, which extends from the second to the seventh costal cartilage and carries nerve, blood and lymph supply. As long as this pedicle remains intact there is no danger of necrosis resulting from interference with the blood supply.

Reduction.—With the lateral portion of the delivered breast in the left hand, the amount of excess tissue is estimated, and with a clean excision the surplus in the infralateral quadrant is removed (fig. 7*A*). The supralateral quadrant is conserved to prevent damage to the lateral

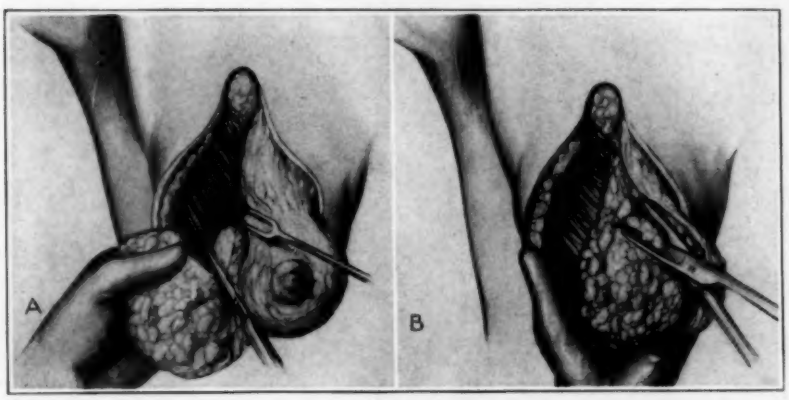

Fig. 7.—*A*, excision of surplus tissue in the infralateral quadrant. *B*, shaping of the lateral margins preparatory to rotation.

thoracic branches of the axillary artery. The remaining breast tissue is shaped ventrally and dorsally, so that it tapers toward the periphery; as much of the central breast substance as possible is left intact. (fig. 7*B*).

Molding.—A supralateral incision is made through the entire thickness of the denuded portion of the breast, so as to permit rotation of the lower segment under the upper (technic suggested by Claoue). The lower lateral pole is plicated under the supralateral quadrant, thereby elevating the breast on the thorax and causing it to assume a hemispherical shape (fig. 8).

Fixation.—The plicated flaps are sutured to each other, and the base of the gland is fixed to the pectoral fascia and muscle with catgut. The number of sutures required is a matter of personal preference; I use two or three for the gland flaps and from eight to ten for attaching the base to the pectoral muscles and fascia (fig. 9).

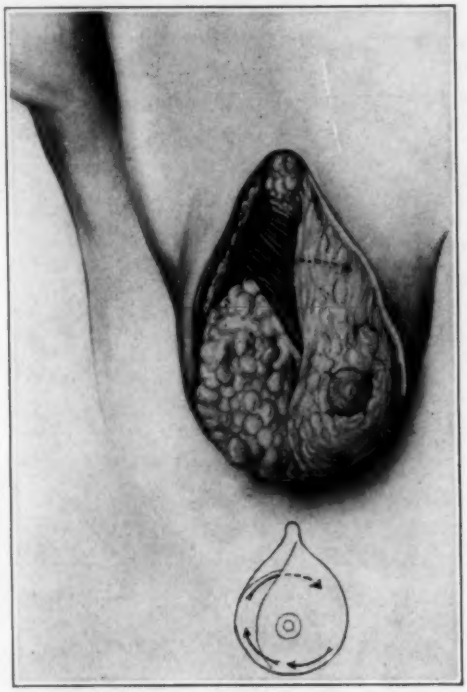

Fig. 8.—Rotation of the inferior pole under the supralateral quadrant.

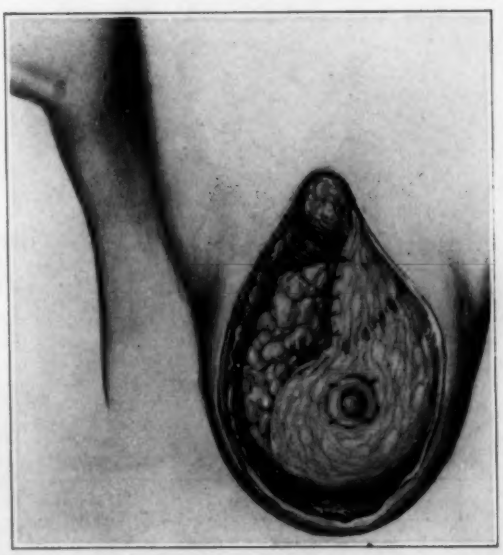

Fig. 9.—The breast rotated, flaps fixed to each other and to the chest wall.

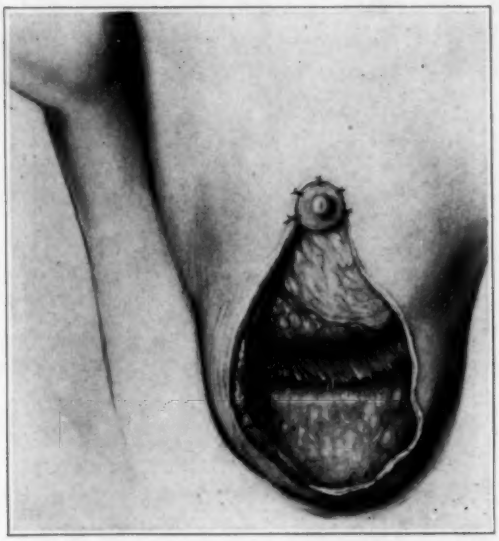

Fig. 10.—The transplanted areola sutured to the skin.

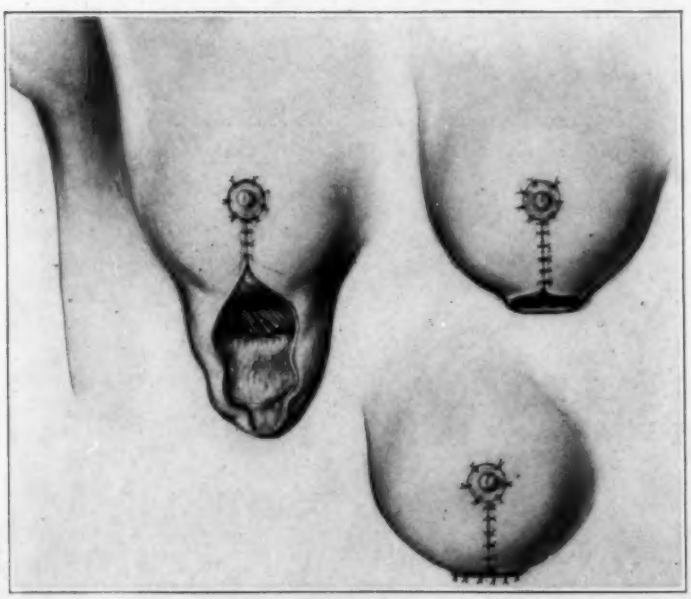

Fig. 11.—Management of redundant skin.

Transplantation of the Areola.—The edges of the areola are undermined for about 1 cm., to prevent constriction of the blood vessels should inadvertent torsion take place. It is placed in the new aperture previously made for it, and the initial four silk retaining sutures are

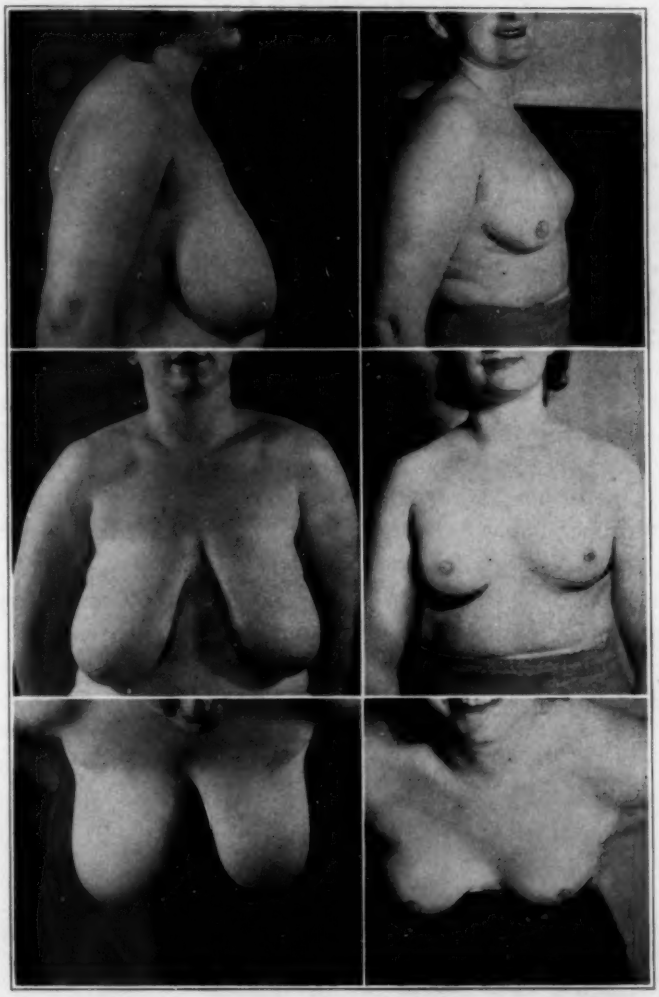

Fig. 12.—Views of a patient before and after operation.

removed. The areola is fixed in its new bed by four subcutaneous catgut sutures; care is taken not to rotate the nipple. The balance of the fixation is done by fastening the areola to the skin with horsehair, using about four sutures to the inch (fig. 10.)

Removal of Redundant Skin.—Redundant skin in the axillary region is fixed to the superficial fascia with as many catgut sutures as are necessary to obliterate dead spaces.

The skin is laid loosely over the reduced breast and held in place by ordinary towel clamps. At this time an idea of the amount of skin to be removed is obtained. As the skin offers no support, a minimum should be excised; even a slight redundancy is permitted. Because of its inherent elasticity it will spread itself evenly over the smaller breast. Excision of the skin below the areola is made from above downward. The edges are coapted with interrupted on-end mattress silk sutures, and the towel clamps are not removed until the sutures have been placed.

At the base of the gland a semilunar excision of skin is required before the line of suture can be continued. It may be possible to elongate the denuded area by a hook placed at either end so that the suture is continued in a vertical line. Frequently it is necessary to close the remaining wound transversely (fig. 11). Scarring is not considerable if a minimum of skin is removed.

Dressing.—Two rubber drains are placed at the dependent angles of the wound and removed in twenty-four hours. Occasionally it is advisable to pass a counterdrain into the axilla through a cutaneous incision made for that purpose. A copious dressing is applied with sufficient pressure to prevent collection of hematomas. Biddle suggested that pressure be obtanied by the use of a bag inflated to a pressure of 20 mm. of mercury. I have had no experience with this dressing, but it seems to be a good procedure.

After-Treatment.—Although the operation borders on being a major one, experience shows that it is well borne. Recovery is rapid, and the relief is great. Serious complications are rare, provided a sufficiently wide medial pedicle is left intact.

The patient may sit up in bed on the third day. Every other stitch is removed on the fifth day, and by the eighth day all have been removed.

ANEURYSMS OF THE HAND

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Although false arterial aneurysm due to arterial injury is the most common type of aneurysm of the hand, great interest is aroused in the arteriovenous fistula, which may be either of congenital or of traumatic origin.

Broca, in his work on aneurysms and their treatment, published in 1856, stated that Sennert had been given credit for describing arteriovenous aneurysm but that actually he described only some of the symptoms due to the condition. However, in that detail he was antedated by Antyllus. Hunter[1] presented the first known case and described arteriovenous communication in 1757, before the Medical Society of London. In his case the basilic vein communicated with the humeral artery. In March 1761 Delacoumbe,[2] in France, dissected a spontaneously developing aneurysm of the femoral artery and was surprised to find a vascular connection with the crural vein. This observation of a dissection of an arteriovenous aneurysm was not only the first to be described but, according to Broca, was the earliest record of a spontaneously developing arteriovenous aneurysm.

In an excellent paper on congenital arteriovenous fistulas, Lewis[3] in 1930 collected reports of thirty cases from the literature. In nine of these the condition involved the hand.[4] Since 1928 there have been reported the cases of Horton and Ghormley.[5]

The patient whose case I shall report was admitted to the service of Dr. Clifford Grulee, who asked me to see him.

John D. White, aged 9 years, entered the Presbyterian Hospital, Chicago, on Feb. 11, 1935. About a year before the parents noticed that the middle and ring fingers of the left hand were longer, larger and darker in color than the other fingers of the same hand or those of the right hand. The boy volunteered the information that about the time that these observations were made he had acci-

1. Hunter, William: M. Obs. Soc. Phys. London **1**:323, 1757.
2. Delacoumbe: J. de méd., chir., pharm., Paris **17**:289, 1762.
3. Lewis, Dean: Lancet **2**:621, 1930.
4. Krause: Arch. f. klin. Chir. **2**:142, 1862. Gherini: Gaz. d. hôp., 1867. Obalinski and Browicz: Zentralbl. f. Chir. **3**:43, 1875. Nicoladoni: Arch. f. klin. Chir. **18**:252, 1875. (Nicoladoni reported a second case in 1876.) Sonntag: Ergebn. d. Chir. u. Orthop. **11**:99, 1919. Rösler, H.: Klin. Wchnschr. **8**:1621 (Aug. 27) 1929. Pemberton, J. de J., and Saint, J. H.: Surg., Gynec. & Obst. **46**:470, 1928. Ballin, M.: J. Michigan M. Soc. **12**:265, 1913.
5. Horton, B. T., and Ghormley, R. K.: Proc. Staff Meet., Mayo Clin. **8**: 773 (Dec. 20) 1933.

dentally caught his fingers in the door of a taxicab. The parents had not been told of the accident. The boy was healthy and active. There was no complaint of disability in the use of the hand, of unusual sweating or of pain in the affected hand.

On general examination no abnormalities were noted. The heart was not enlarged; the rate was not increased, and the blood pressure in the right and the left arm was the same. The lower extremities were symmetrical and normal. The left arm was 1.5 cm. longer and slightly larger in circumference than the right. The boy, however, was left-handed. The superficial veins of the left forearm were more prominent than those of the right. The left hand was warmer than the right and was slightly cyanotic. The third and fourth fingers were 1.5 cm. longer than those of the right hand and at least one-third greater in circumference. The digital veins were greatly dilated and showed considerable arterial pulsation. There was a decided capillary pulse in the nails of these fingers. The involved fingers were much warmer than the others, and a definite pulsation and a slight thrill were felt in them. In the palm of the hand, at the base of the third and fourth phalanges, a thrill was palpable, which faded toward the wrist. On auscultation a loud humming continuous bruit, with sharp high-pitched systolic notes occurring synchronously with the heart beat, was heard over the whole hand and fingers, as well as in the forearm to the brachial artery, where it became faint. The sounds were loudest at the base of the fourth phalanx in the palm; I believed this observation to be most important in determining the site of the surgical point of attack on the arteriovenous communication. When a stethoscope was placed on this point and when the ulnar artery in the wrist was compressed, the two bruits almost disappeared, whereas compression of the radial artery affected the noises little. Compression of the brachial artery in the antebrachial fossa, as well as of both radial and ulnar arteries in the wrist, caused complete disappearance of the bruits. In no instance was a bradycardic reaction observed. On compression of the ulnar artery in the wrist, the venous pulsation of the fingers disappeared.

The following observations were apparent from the results of the examinations: that an arteriovenous fistula was present; that it was probably congenital, since the only possible injury that had occurred was in the fingers, while the principal lesion was in the palm; that the site of the arteriovenous communication was probably greatest in the superficial palmar arch and especially at the point where the digital arteries were given off; that a possibility of communication with the deep palmar arch existed, because of the necessity of shutting off both radial and ulnar arteries to stop the bruit entirely.

Dr. C. J. Lundy made injections in order to determine by roentgenographic examination the site of the arteriovenous fistula and whether there were one or more communications. The results were as follows: 1. Skiodan injected into the dorsal vein of the hand failed to show the arterial communication. 2. Skiodan injected into the radial artery at the wrist failed to show the venous communication. 3. Skiodan injected into the ulnar artery indicated that the site of the arteriovenous fistula was probably in the superficial palmar arch. Operation was performed on Feb. 18, 1935, with the patient under ethylene and ether anesthesia.

A Martin bandage was placed on the left arm of the patient, and a longitudinal incision was made parallel to the hypothenar eminence, which divided the annular ligament and exposed the superficial palmar arch. A definite communication between the artery and the veins of the superficial palmar arch

Fig. 1.—Arteriovenous aneurysm of superficial and deep palmar arch, with marked hypertrophy of third and fourth fingers.

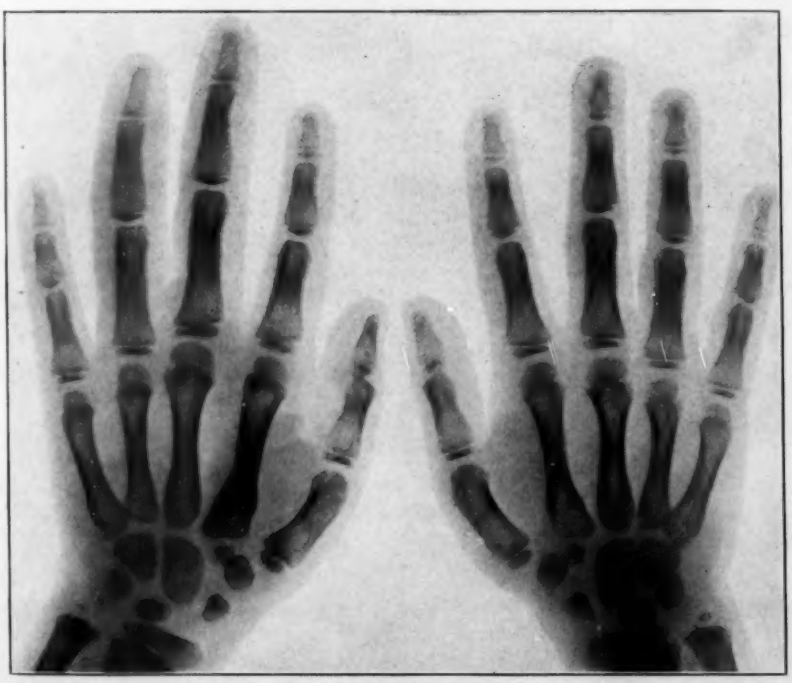

Fig. 2.—Arteriovenous aneurysm of superficial and deep palmar arch, showing overgrowth of phalanges of second, third and fourth fingers.

and a smaller and less definite communication between the superficial palmar arch and the veins of the deep palmar arch were noted. The third and fourth digital veins were greatly dilated. About 1½ inches (3.8 cm.) of the ulnar artery, including the digital arteries and veins to the third and fourth fingers, was ligated and removed, as well as the dilated communicating branches to the deep palmar arch. The radial artery was not ligated.

Fig. 3.—Arteriovenous aneurysm of superficial and deep palmar arch. Injection of skiodan into ulnar artery shows communication between the superficial palmar arch and the veins to the fourth and fifth fingers.

After the operation the double bruit in the palm and fingers disappeared, and the venous pulse in the veins of the fingers was slight. The third and fourth fingers were less congested and the veins much smaller. Over the radial artery in the wrist, and to lesser degree over the thenar eminence, a double bruit could still be faintly heard if the pressure of the stethoscope belt was exactly right. It was my impression that ligation of the radial artery would eventually be necessary.

An examination of the hand revealed no bruit over the radial or ulnar artery in the wrist or in the palm. The venous pulse had entirely disappeared; the veins in the third and fourth fingers were no longer dilated, and the impression was gained that these fingers were not as prominent as before. Apparently the principal arteriovenous fistula had been removed, although it was thought that smaller ones might be present and might develop later in view of the fact that after the operation a slight double bruit was present in the radial artery and a venous pulse in the fingers was faintly visible.

The most striking aspects of the case are the insidious onset with a doubtful traumatic factor, the considerable hypertrophy of the third and fourth fingers immediately distal to the arteriovenous fistula, the definite venous pulse and capillary pulse, the increased warmth of the hand and the reliability of the stethoscope in determining the point of greatest intensity of the double bruit and, consequently, the site of the arteriovenous fistula. In this case the visualization of the arterial tree and the immediate filling of the veins after the injection of skiodan into the ulnar artery were interesting but did not conclusively define the site of the arteriovenous fistula. In Horton and Ghormley's case the fistula was plainly visualized.

The cardiovascular symptoms are usually absent when the arteriovenous fistula is in the hand or finger, owing to the fact that less blood passes through the fistula. With the type of congenital arteriovenous fistula under consideration, the process often involves the arm secondarily or coincidentally, to a greater or less extent, in which event bradycardia may be present. This fact was noted, as Dean Lewis pointed out, by Nicoladoni and also by Pemberton. In the cases in which extension of the process into the arm has occurred many or all the cardiovascular phenomena carefully tabulated by Lewis and Drury [6] may be present. They are as follows:

1. General arterial pressure (*a*) Normal systolic pressure and low diastolic pressure, resulting in water-hammer pulse (*b*) Low systolic pressure, distal to arteriovenous fistula (*c*) Hill and Rowland's differential pressure sign: difference between systolic pressure of arm and of leg.
2. Capillary pulse
3. Venous pulse
4. Collapsing pulse
   Summit of pulse ill sustained
5. Heart rate slightly increased
   Closure of fistula leads to conspicuous fall of rate below normal reading
   This condition is vagal in origin and is abolished by atropine
6. Output of heart the same
7. Enlargement of the heart due to diminished flow of blood through the coronary vessels

6. Lewis, T., and Drury, A. N.: Heart **10**:301, 1923.

Hypertrophy of the extremity complicated by congenital arteriovenous aneurysm has been graphically described by Lewis, Reid [7] and Horton. Broca gave Giraldes credit for first describing, in 1854, the lengthening of the limb in these cases. It occurs only in open epiphyses. In Horton's series of twenty-three cases the involved extremity was from 2 to 8 cm. greater in circumference than the normal leg and was from 0.5 to 7 cm. longer.

Of the eleven cases of congenital arteriovenous fistula in which the lesion was principally in the hand or fingers, in eight there was some hypertrophy of the affected extremity, in seven an increase in the length of the whole arm, in three an increase in the size of the whole hand and in two hypertrophy of one or more fingers (fig. 1). Pain was present in only one case. Increase in heat of the affected part was generally observed, and considerable sweating of the hand was noticed in two cases.

Of the eleven cases of primary involvement of the hand, the palm, dorsum and fingers were affected in four, the palm alone in three and the fingers alone in four. In nine of these cases there was some secondary involvement of the arm evidenced either by extension of the arteriovenous fistula into the vessels of the arm (in four cases) or by hypertrophy of the whole extremity with enlargement of the veins of the arm (in four cases).

In only one of these cases was the lesion noticed at birth; in three cases it was observed when the patient was between 1 and 2 years of age, and in the rest of the cases it was first noticed when the patient was between 7 and 20 years of age.

The underlying pathologic changes are not definitely known, but for purposes of clinical discussion it is probably best, as Horton suggested, to include under the head of congenital arteriovenous fistula lesions such as cirsoid aneurysm, arteriovenous varix and pulsating venous aneurysm.

In the treatment of these eleven patients varied procedures were used: amputation of the extremity in two cases; amputation of fingers in three cases; ligation of the enlarged veins in one case; compression of the fistula in one case; ligation of the radial artery later followed by ligation of the ulnar artery in one case; ligation of both radial and ulnar arteries at first operation in one case, and ligation of the superficial palmar arch in two cases.

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7. Reid, M. R.: Studies on Abnormal Arteriovenous Communications, Acquired and Congenital: Report of a Series of Cases, Arch. Surg. **10**:601 (March) 1925; Abnormal Arteriovenous Communications, Acquired and Congenital: Effects of Abnormal Arteriovenous Communications on Heart, Blood Vessels and Other Structures, ibid. **11**:25 (July) 1925; Abnormal Arteriovenous Communications, Acquired and Congenital: Treatment of Abnormal Arteriovenous Communications, ibid. **11**:237 (Aug.) 1925.

The ligation of the arteries mainly involved in the lesion effected at least temporary improvement, though the long term result is doubtful. The amputation of the fingers apparently resulted in cure. The ultimate outcome necessarily depends on the extent of the lesion.

TRAUMATIC ANEURYSM OF THE HAND

An aneurysm of the hand developing directly as the result of trauma is by far the most common form of the disease and is due almost always to weakening of the arterial wall either by blunt force, which causes a subsequent aneurysmal dilatation, or more commonly by sharp force, such as a wound from a knife or glass, which injures the division of the artery and results in the development of a false aneurysmal sac. A much rarer condition and, in fact, one that it is difficult to find record of in the literature, is arteriovenous aneurysm which develops as the result of direct simultaneous injury of the artery and veins.

Lyle [8] found reports of sixty-one cases of aneurysm of the hand in the literature up to 1924, and Vohlmann [9] in 1930 reported on a series of sixty-seven cases reports of which he collected from the literature from 1922 to 1930. These records are probably not a fair indication of the frequency of the occurrence of the condition, as many of the relatively trivial aneurysms of the hand are not regarded as interesting enough to report. The superficial palmar arch is much more frequently injured than the deep arch; the ratio was 54:8 in Lyle's series. Severe bleeding at the time of injury must be regarded with suspicion. Eighty per cent of the patients had repeated hemorrhages. The aneurysmal sac varied in size from that of a pea to that of an apple and made its appearance from twelve hours to five months after the injury. Almost all the aneurysmal sacs are false, since they are due to lamellation and fibrosis of a hematoma which connects with a defect in the artery. A systolic murmur is heard over the sac, but thrills are rare.

The treatment should be radical; excision of the sac is much better than ligation of the vessels that enter and leave the sac, since failure to effect a cure after the use of the method of ligation has been reported.

The two cases of traumatic aneurysm of the hand to be reported are of interest in that in both the condition involved the radial artery on the dorsum of the hand in the snuff-box space, formed by the extensor pollicis longus and the extensor pollicis brevis muscle, and that in one case both the artery and the vein were involved in the formation of the arteriovenous fistula, which was accompanied by arterial and venous bruits.

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8. Lyle, H. M.: Ann. Surg. **80**:347, 1924.
9. Vohlmann: Deutsche Ztschr. f. Chir. **227**:151, 1930.

The first case is that of a false aneurysm of the radial artery in the snuff-box space:

A. P. W., a man 20 years old, entered the Presbyterian Hospital on May 28, 1931. About six weeks before entry the patient was in an automobile accident and received a cut from glass over the dorsum of the right hand. Profuse bleeding occurred, which was controlled by two stitches. The wound healed and nothing unusual was noticed at the site of the injury until two weeks before entry, when a swelling developed in the snuff-box space, which gradually increased in size until it was the size of a walnut. There was no pain, but stiffness in the wrist interfered with his work.

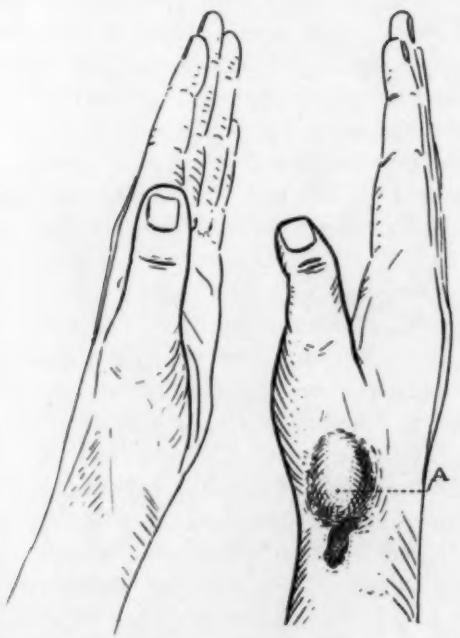

Fig. 4.—Arteriovenous aneurysm of the radial artery and vein, due to injury by shrapnel. *A* indicates the aneurysm in the snuff-box space, filling the shrapnel wound.

The physical examination gave negative results except for the presence of a pulsating tumor over the course of the radial artery on the dorsum of the hand. No bruit was heard over the tumor, nor was there a palpable thrill.

At operation, performed on May 29, 1934, with the patient under ethylene anesthesia, a Martin bandage was used. An incision along the center of the snuff-box space revealed a false aneurysmal sac, made up of a lamellated blood clot, which communicated with an opening in the radial artery about 1.5 mm. in length. The false sac was about 4 by 4 cm. It was removed, and the radial artery was ligated proximally and distally to the opening in it. The vein was not involved. The patient made an uninterrupted recovery, with no motor or sensory disturbances.

The second case is concerned with a war wound that was caused by a small piece of shrapnel entering the snuff-box space of the right hand and that resulted in an arteriovenous aneurysm of the radial artery and vein.

Oscar A. N., a private, was wounded by a small piece of shrapnel that entered the snuff-box space of the right hand on July 15, 1918. Immediately after the injury and to the time of the operation he was unable to extend the distal phalanx of the right thumb, which stood stationary at almost a right angle to the first phalanx. There was, however, no injury to the nerve supply.

Examination on August 11 revealed, in addition to the division of the extensor pollicis longus muscle, a definite thrill over the snuff-box space of the right hand. The thrill was palpable over nearly the entire dorsum of the hand and along the radial artery in the wrist. Auscultation revealed a continuous tremor, punctuated by sharp arterial pulsations which resembled in sound footsteps coming down an empty hall heard over a telephone. Both bruits were heard along the course of the artery in the forearm and along the brachial artery to the axillary space, as well as over the whole hand. There was no venous dilatation or venous pulse in the hand. The arteriovenous bruit was loudest over the snuff-box space. The formation of the tumor was slight.

An operation was performed on August 26, with the patient under ether anesthesia. An incision was made from the base of the first metacarpal of the right hand along the course of the extensor pollicis longus to the middle third of the forearm. Deep in the snuff-box space, embedded in scar tissue, was found a small nodular swelling, 2 by 1 cm., which consisted of a fusion of the radial artery and vein. The tumor was ligated proximally and distally and removed. The divided ends of the extensor pollicis longus muscle were found and sutured together with silk.

On September 18 there was a slight discharge of old blood from the wound. All signs of the aneurysm had disappeared, and the patient was able to move the distal phalanx of the thumb.

In this case of traumatic arteriovenous fistula, scar tissue around the aneurysm prevented the development of a tumor of magnitude, and probably because of it and the recent development of the fistula, sufficient time had not elapsed to allow the veins of the hand to dilate and to show venous pulsation. As in the other case of arteriovenous fistula of the hand, insufficient blood was short-circuited into the venous system and so caused general circulatory disturbances, though in the last case the test for bradycardia was not applied.

STUDIES IN GASTRO-INTESTINAL MOTILITY

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Of the many technical methods employed in the study of gastro-intestinal motility, none fully escapes criticism. Objections commonly fall into three groups: The animal is, as a rule, anesthetized; a certain amount of trauma is usually entailed, and, finally, the methods of recording are to a certain degree deceptive and misleading in that intestinal activity is either visibly perceived or recorded as a volumetric change in the lumen. In this paper a new method and its application will be presented. While all the objections are not overcome, especially in regard to trauma, the method possesses distinct advantages over any other in use at present. The experiments are conducted on unanesthetized animals; the action of both muscular coats is individually recorded, and, finally, it is possible to apply stimuli to the mucosa in a manner simulating the passage of normal fecal contents.

The paper will be presented in two parts, the first dealing with the method and the preparation and the second with the application of the method to certain physiologic problems.

METHOD OF INVESTIGATION

The principle involved in this method embodies the exteriorization of a segment of bowel (or stomach) by means of grafting to the abdominal wall.

OPERATIVE PROCEDURE

To prevent contamination with urine, medium-sized female dogs are chosen which appear suitable for training and conditioning. Through a left rectus incision the desired portion of bowel is delivered, and a segment supplied by a single vascular arch is selected. This segment is resected (fig. 1 *A*), leaving the mesentery with its structures intact. An end-to-end anastomosis is performed between the resulting proximal and distal ends to re-establish continuity; the mesenteric defect is closed, and the intestine is dropped back into the abdominal cavity. The abdominal wall is closed around the mesenteric pedicle in layers to the subcutaneous tissues. An area of skin corresponding roughly in

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size to the expected graft is then excised, leaving as much of the subcutaneous tissue as possible. The segment of bowel is next opened in a linear direction along the antimesenteric border (fig. 1 *C*); fecal material is removed, and the mucosal surface is cleansed with saline solution and alcohol. The opened bowel is approximated to the defect in the skin, and the edges are attached to the skin by sutures, which include the full thickness of the graft on one side and the skin and a small amount of subcutaneous tissue on the other. A few interrupted sutures placed beneath the graft serve to approximate the serosa and the subcutaneous tissue and to obliterate dead space.

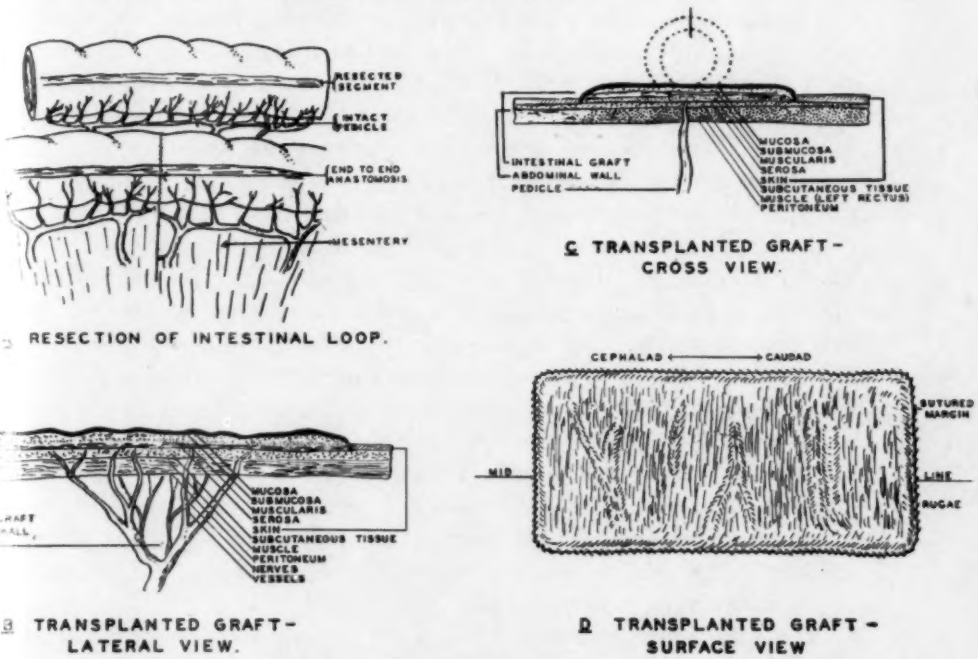

Fig. 1.—Drawings showing stages of the operative procedure in the grafting of a segment of the intestine.

The procedure for the stomach differs slightly in that a segment is removed from the greater curvature, including a narrow strip from both the anterior and the posterior wall. The pedicle in this case includes branches of the lienal vessel, through which the blood supply is obtained, the pancreaticoduodenal branch being ligated. The gastric defect is closed by inverting and suturing the edges, serosa to serosa. It must be pointed out that in this preparation the branches of the vagus nerve are cut across, and hence the graft does not retain its full nerve supply.

The finished graft (fig. 1 *D*) is covered with petrolatum gauze, and the surrounding skin is generously smeared with boric acid oint-

ment to prevent irritation and digestion by the intestinal secretions. A pressure dressing is held in place by a light muslin coat. Dressings should be changed every day for a week, after which they may be discarded. It is almost impossible to prevent a certain amount of contamination, and some infection is to be expected. By loose suture of the edges, however, ample drainage is provided, and the graft "takes" and heals by primary intention in the majority of instances. Even when one or more edges separate from the skin, the graft remains viable, and healing, though delayed, is complete.

Training is started immediately after the operation, in order that the animal may be ready for experimentation when healing is complete. This is done by placing the dog on its right side on the apparatus table. Covering with a light sheet helps the conditioning process. Force and even punishment may be necessary to gain cooperation, but with a reward of food the animal soon accepts authority and lies quietly for increasing periods.

The recording apparatus, which is shown in the illustration (fig. 2), employs the use of a modified enterograph consisting of two units. Unit 1 is attached by spring clips to the mucosa at either end of the graft in a longitudinal direction and records the movements of the longitudinal muscle. Unit 2 is superimposed on the first and is attached in the same manner to opposite sides of the graft so as to record the contractions of the circular muscle, all movements being transmitted to a smoked drum on the kymograph by means of levers. Thus, the activity of the individual muscular coats is shown on a smoked drum simultaneously with the time and signal tracings. Gross movements of the animal mar the records, but the minor deviations of the writing levers due to respiratory movements offer no real difficulty in the interpretation of results.

The graft thus prepared is suitable for experimentation for a period of from six to twelve months, depending on the portion of the bowel used and the amount of irritation to which it is subjected. Although the muscle continues to be active and responds to stimulating influences for a longer period, metaplasia, with hardening of the mucosal surface, makes application of the recording clips difficult and vitiates the accurate interpretation of the tracings. It is interesting to note that these changes occur most rapidly in the grafts of the colon, which are rarely useful for more than six months. Sections of the jejunum and ileum, on the other hand, have remained useful for as long as twelve or fifteen months.

PATHOLOGIC CHANGES

It is appropriate at this point to speak briefly of the pathologic changes occurring in the grafts, as noted in specimens removed at

various intervals after operation. Sections taken through an entire graft have demonstrated the complete fusion of the serosa to the underlying subcutaneous tissue as well as the fusion of the mucosa to the skin. The muscle coats were hypertrophied, and the submucosa

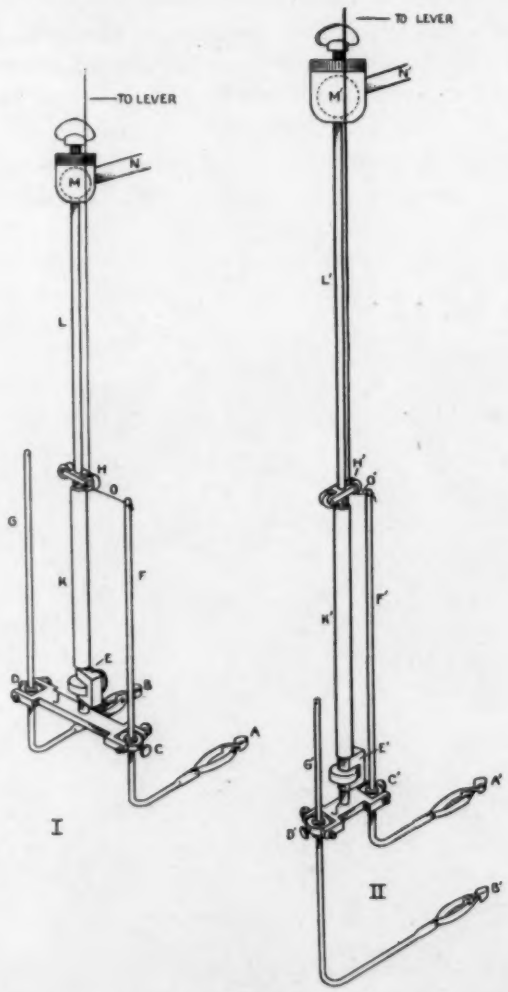

Fig. 2.—Diagram of a modified enterograph, consisting of two units. In unit *I* the spring clips *A* and *B* are attached to the mucosa to be tested. Clip *B*, with its attached lever, *G*, is fixed. Clip *A*, with its rod, *F*, is fastened by a universal joint, *C*, to a bar, *J*, and moves with the changes in distance between *A* and *B*. These movements are transmitted by the string, *O*, through a pulley to the levers of the kymograph. The bar, *J*, rotates on the rod, *L*, which in turn is supported by a ball-and-socket joint, thereby minimizing the deviations of the writing levers in response to the movements of the animal. Unit *II* is superimposed on unit *I* and records in a similar manner the movements of the circular muscle.

was thickened. The muscularis mucosa remained intact unless the graft had been subjected to unusual trauma. The vascularity of the entire preparation, as might be expected, was markedly increased, owing to the development of collateral circulation. The most pronounced changes were observed in the mucosa.

Progressive disintegration of the normal glandular structures was seen in all preparations, depending on the age of the preparation and the amount of trauma. The first noticeable change was wearing off of the tips of the villi, with slight distortion of the superficial portion of the glands. Later the mucosa was often covered by a thin layer of fibrin, which in late stages became organized. Shutting off the openings of the crypts sometimes impeded the escape of secretory products, with subsequent cystic dilatation at the bases. Of greatest importance

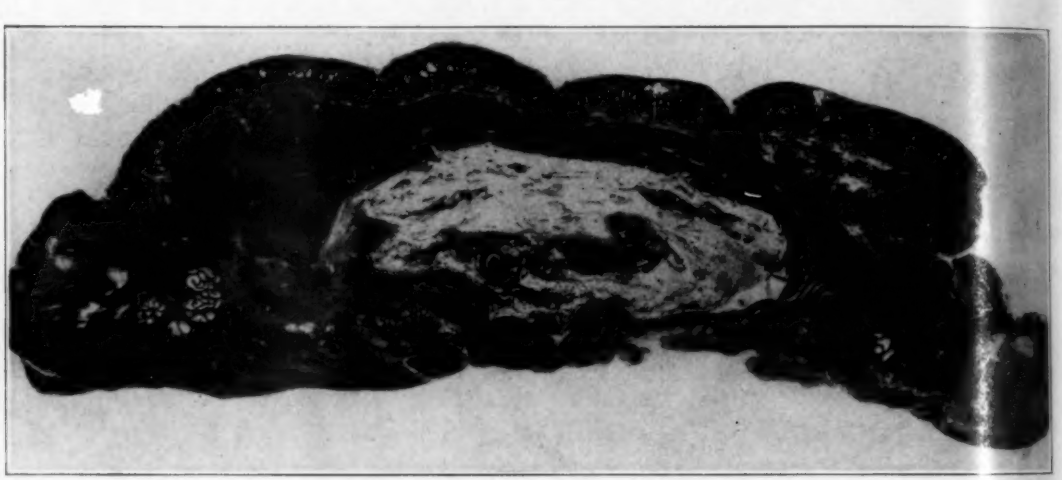

Fig. 3.—Low power photomicrograph of a section taken transversely through the midportion of a graft from the ileum at the end of five months. The points of contact with the skin, the hypertrophy of the muscle and the relatively normal appearance of the mucosa are evident. The light area in the center indicates properitoneal fat, and in it can be seen the vessels of the pedicle.

was the histologic evidence of regeneration of the glandular epithelium, demonstrating that the mucosa is not devitalized by transplantation to a strange environment (figs. 3 and 4).

It is of interest to note that occasionally, but not invariably, peninsulas of squamous epithelium grow out from the edges of the skin, forming almost isolated islands as large as 1 cm. in diameter. That these occur in areas denuded of mucosal epithelium is suggested by the absence of glandular structures beneath them. The remarkable regenerative powers of the grafted portion of bowel were illustrated

in an animal in which a newly prepared flap was almost chewed off. The defect closed in rapidly by a fungating mass of granulation tissue, which later retracted to the size and thickness of the original graft. The mucosal epithelium was not replaced, however, and six months

Fig. 4.—High power photomicrograph of the section shown in figure 3. The superficial fusion of the tips of the villi, with beginning disintegration, the dilatation of the bases, the beginning disruption of the muscularis mucosa and the hypertrophy of the submucosa are apparent.

later, when the graft was removed, it presented the histologic appearance of the base of a chronic ulcer, with marked fibrosis and cellular infiltration.

BASIC REACTION

Before one proceeds to the description of specific experimental work, it is necessary to establish what may be termed the basic reaction of the graft under the existing conditions. A muscular response is invariably noted immediately after attachment of the clips, due no doubt to the irritation of attachment. This activity assumes the form of a series of reciprocal contractions of each muscle coat, lasting from one to two minutes but rarely constant either in magnitude or in duration. It is at this point, however, that a significant fact is noted. These contractions invariably occur at intervals of constant frequency. In the small intestine the interval is from four and a half to five seconds, while in the colon it is between fifteen and sixteen seconds. This is designated as the oscillatory frequency of the intestinal musculature, and it remains fairly constant, irrespective of the type of stimulation employed to incite muscular activity (to be described later).

Once the effect of attaching the clips has passed, the recording levers reach a base line. This represents the basic intrinsic activity and differs according to the portion of bowel tested. Thus, while no portion demonstrated active motion during the fasting state, after the ingestion of food there was observed the institution of an inconstant cycle of activity. In the jejunum and ileum this consisted of a series of minor contractions of both muscle coats at the established oscillatory frequency (from four and one-half to five seconds). These minor contractions appeared in definite cycles of magnitude, which recurred at intervals of from five to eight minutes. In the colon two important differences were noted. Although the oscillatory frequency (from fifteen to sixteen seconds) was maintained, there were no definite cycles, and the individual contractions were of less magnitude. While it is difficult to determine which muscle coat is primarily affected in the food reflex, the circular muscle appears to predominate.

To summarize briefly, two important facts are established: 1. All intestinal musculature exhibits minor rhythmic contractions of a definite oscillatory frequency in addition to the changes in tone, or major contractions, regardless of the type of stimulus producing the activity. 2. A muscular reflex is instigated by the ingestion of food into the stomach, which is manifested in all parts of the bowel. The second phenomenon coincides with the findings of other investigators and represents the graphic proof of the so-called food reflex, a physiologic fact illustrated by the desire to defecate after partaking of food. That this is a central or spinal cord reflex is demonstrated by its absence after severance of the mesenteric pedicle with its nerve supply. It is to be emphasized, however, that the preceding statement applies only to the intestinal tract, as neither type of contraction has been observed in the stomach preparations tested.

APPLICATION OF THE METHOD

MECHANICAL STIMULATION

It was found, quite by accident it must be confessed, that light stimulation of the mucosa produced a definite and constant response of the intestinal musculature. With the use of a standardized stimulus of ten strokes with a blunt teasing needle administered for a period of from eight to ten seconds, attempts were made to analyze the intestinal response. Thus, it was found that with the recording clips attached at opposite sides and ends of the graft, as already described, stimuli applied throughout its length near the center produced strong contrac-

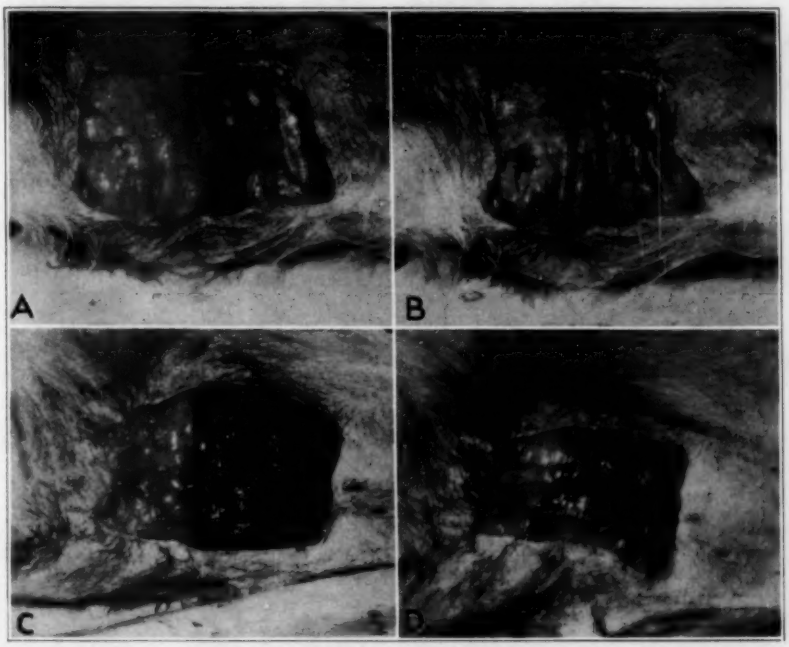

Fig. 5.—Photographs showing stages of contraction in the graft from the colon. *A* represents the normal graft; *B*, contraction of the longitudinal muscle after longitudinal stimulation; *C*, contraction of the proximal half of the graft only after transverse stimulation near its center, and *D*, contraction of the circular muscle throughout almost the entire graft after circular stimulation at the distal end.

tion of the longitudinal muscle, with coincident relaxation of the circular muscle. This was followed shortly by contraction of the circular muscle and relaxation of the longitudinal muscle. If the stimuli were then applied transversely between the clips, a definite change of reaction was noted. The initial contraction of the longitudinal muscle was present but was of less magnitude, while the initial contraction of the circular muscle was stronger and occurred more quickly after the initial application of the stimulus (figs. 5 and 6). This is explained

on the basis of the transmission of nerve impulses to more sensory end-organs of the longitudinal muscle coat in the first instance and to more end-organs of the circular muscle coat in the second. This, in general, is the typical response of all portions of the intestinal tract. There are, however, certain characteristic differences in the types of contraction elicited in different parts of the intestine, which are manifested chiefly in the predominance of the muscle coat involved and the time relations of stimulation and contraction.

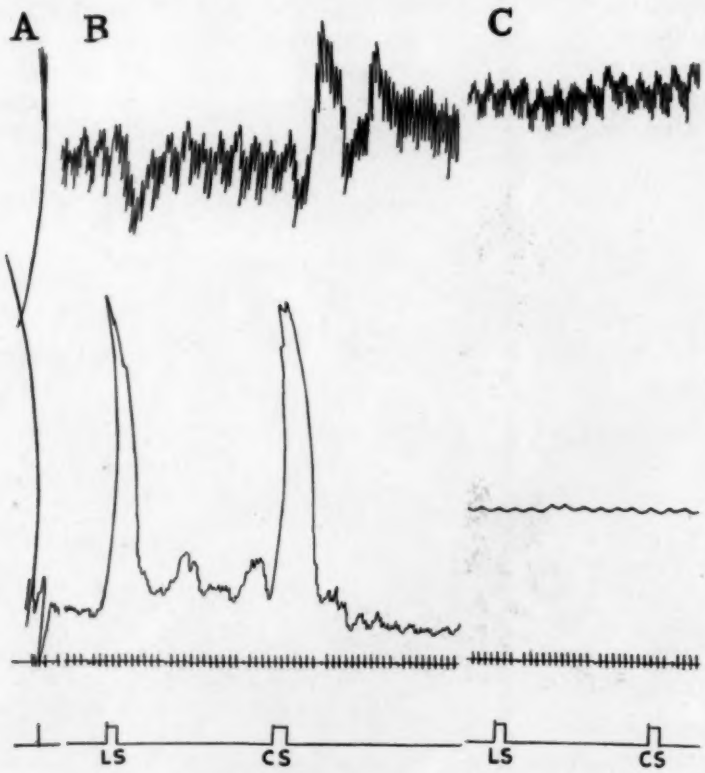

Fig. 6.—Tracing on a smoked drum of a typical contraction after longitudinal (*LS*) and circular (*CS*) stimulations. *A* shows the tracing by which the contractions are measured for their time relationships; *B*, the response of the normal graft to both types of stimuli, with the minor rhythmic deviations of the circular muscle at intervals of approximately fifteen seconds, (the animal had been fed one-half hour before the tracing was taken), and *C*, the response after atropine had been injected. The food reflex (minor rhythmic contractions) persists, but all response to mechanical stimulation has been lost.

In none of the stomach grafts observed was typical muscular activity elicited by any type of stimulation. The reason for this cannot be given at present, but the fact that the branches of the vagus nerve were severed may be responsible in part.

In the jejunum the contraction of the longitudinal muscle was of moderate magnitude after longitudinal stroking and of minimal magnitude or even absent after stimulation in the transverse direction. The contractions of the circular muscle predominated after both types of stimuli, the only differences being in the abruptness of the contraction and its duration. Both the major contractions were accompanied by minor rhythmic oscillations of the established frequency. In the ileum the contractions of both coats were of less magnitude, appeared to be more sluggish and were rarely accompanied by minor oscillations. The contraction of longitudinal muscle invariably predominated in the colon, but the contractions were smaller after circular than after longitudinal stroking. Activity of the circular muscle was minimal or sometimes absent after longitudinal stimulation and constant and strong after cir-

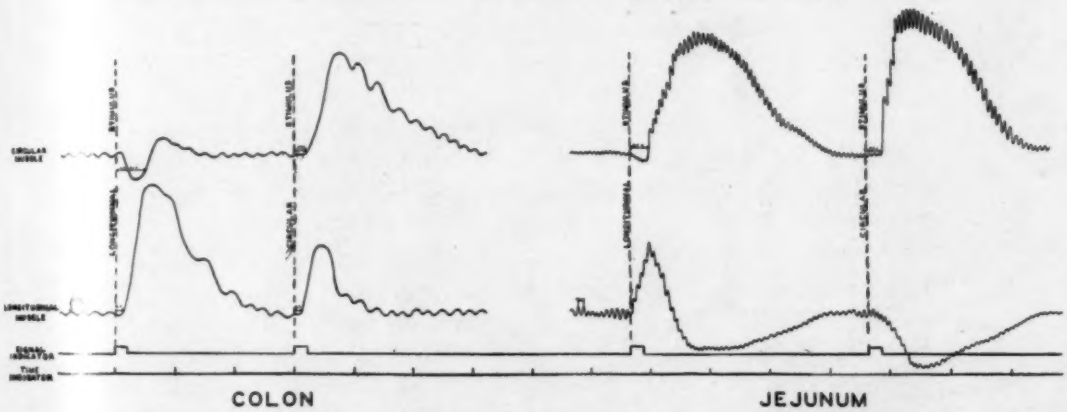

Fig. 7.—Diagrammatic reproduction of typical forms of contraction in the colon and in the jejunum. The preponderance of contractions of the longitudinal muscle in the colon and that of the contractions of the circular muscle in the jejunum are evident. After longitudinal stimulation of the colon the circular muscle reacts little if at all, while the same is true of the longitudinal muscle of the jejunum after circular stimulation. The minor rhythmic oscillations of the jejunal musculature are more exaggerated and rapid. In this diagram and in the diagram shown in figure 9, time is indicated in units of five seconds.

cular stimulation. In figure 7 are illustrated graphically the types of response seen in the jejunum and the colon.

The time relations of contraction and stimulation are most clearly shown in table 1.

The table designates the time, expressed in seconds, elapsing between the initial application of the stimulus and the various phases of the muscular movement, as shown in the column at the left. For the sake of clarity the term latent period is used to designate the time between the stimulus and the initial contraction. Thus, it is seen that in the jejunum the longitudinal muscle reacts more quickly than in other por-

tions of the bowel. The direction of stimulation appears to exert little effect on the latent period, but the duration of the contraction is maintained longer after longitudinal stimulation. The circular muscle reacts more slowly than the longitudinal muscle, but it reacts more quickly after circular than after longitudinal stimulation. The contraction is maintained no longer, however. In the ileum both the muscle coats respond more slowly than in the jejunum, but again the circular coat responds more quickly after circular than after longitudinal stimulation. In the colon the activity of the longitudinal muscle appears more slowly than in the jejunum and faster than in the ileum. The circular muscle reacts more quickly in the colon than in either of the

TABLE 1.—*Time Relations of Contraction and Stimulation* *

Phase	Longitudinal Stimulation*		Circular Stimulation†	
	Longitudinal Muscle	Circular Muscle	Longitudinal Muscle	Circular Muscle
Jejunum				
Latent period	2.5	19.8	3.0	13.8
Height of contraction	9.0	36.7	7.5	24.2
Beginning of descent	22.7	105.4	22.3	65.4
Base line	44.1	133.5	36.5	118.2
Ileum				
Latent period	6.9	28.3	6.1	16.3
Height of contraction	13.5	52.7	21.2	31.9
Beginning of descent	31.4	80.2	44.6	68.8
Base line	54.4	115.7	59.6	100.2
Colon				
Latent period	4.0	14.8	4.9	8.9
Height of contraction	12.0	23.3	11.2	19.3
Beginning of descent	24.8	47.0	29.6	42.4
Base line	49.4	62.3	39.2	65.2

* The time relations are measured in seconds.
† The terms "longitudinal stimulation" and "circular stimulation" as used here and elsewhere in the text refer to the direction in which the bowel was stroked and not to stimulation of the individual muscle coat.

other bowel preparations, and again there is the quickened response after circular stimulation.

Certain features of the preceding description merit further discussion. The relaxation of the circular muscle coincidental to the contraction of the longitudinal muscle may represent either an active or a secondary inhibition. Although definite proof is lacking, associated evidence favors the latter surmise, namely, that the relaxation is a mechanical phenomenon caused directly by the contraction of longitudinal muscle. It is comparable to the stretching of a rectangular sheet of rubber dam in that as the length is increased the width is correspondingly decreased in order to maintain the same surface area. That this is true is suggested by the fact that the inhibition always follows the contraction by a short interval and returns to the base normal with the cessation of the contraction. Further, in an area in which the

circular but not the longitudinal muscle is sensitive to a localized stimulus, there is no inhibition of the contraction of circular muscle after stimulation.

Muscular fatigue may be shown by application of repeated consecutive stimuli. When this is carried out, the initial contraction of longitudinal muscle is similar to that in the instances already described, but is maintained longer. When the circular fibers begin to contract, the longitudinal muscle is partially inhibited (as may be expected in view of the aforementioned principle). It does not return to its normal state, however, and both coats maintain a moderate degree of tonus as long as twenty or thirty minutes, after which the muscle appears to have temporarily lost its contractility. This returns in a short time, however, and contractions of the same magnitude as those obtained before fatigue may again be elicited. If the muscle is allowed to return to its normal state of tone each time before the new stimulus is applied and the process is repeated, contractility is not lost, although the contractions may become weaker.

On review of the aforementioned facts, one immediately considers the location of the reflex arcs responsible for these phenomena. That the reflex is myenteric or local has been shown in several ways. First, and most conclusively, the activity is in no way diminished or altered by section of the mesenteric pedicle with its blood and nerve supply. Second, topical application of cocaine completely abolishes the receptivity of the mucosa to the stimulus at any given point but does not alter the muscular response at that point to a stimulus applied outside the cocainized area in an active zone of stimulation. Third, the subcutaneous injection of atropine abolishes all response to stimulation within a few minutes. Fourth, a double graft has been prepared in which the continuity of the resected segment was broken by section and then reestablished by suture. Stimulation in any portion of one graft elicited no response in the other. Finally, it has been shown that the intestine retains some degree of activity when entirely removed from the body. The intestine of the embryonic rat exhibits a moderate degree of peristaltic activity when kept in Ringer's solution for several days. Further, grafts removed from experimental animals have retained muscular response to pinching of the mucosa as long as one hour after removal if placed in warm saline solution.

To summarize briefly, from a study of the types of contraction and the speeds with which they respond to stimulation, the following concepts of the activity of different portions of the bowel are formed: The jejunum is most irritable, as shown by its quicker response to stimulation and the persistence of minor rhythmic contractions at a definite oscillatory frequency. Further, the contractions of the circular muscle are predominant. Both these facts are in keeping with the function of

the jejunum in the propulsion of semifluid fecal contents. The ileum is more sluggish; its contractions exhibit no rhythmic oscillations, and the changes of both the longitudinal and the circular muscle coat are of less magnitude. The colon is by far the most powerful, as demonstrated by the greater magnitude of both types of contraction, and the contractions of either muscle coat may predominate, depending on the direction of the stimulus, a form of activity to be expected from the function possessed by the colon of manipulating solid fecal material. Finally, it has been shown beyond doubt that this activity results from a myenteric reflex.

LOCATION OF STIMULI

The Law of the Intestine.—During the course of the previous experiments it was noted that transverse stimulation proximal to the point of attachment of the recording clips produced no recorded contraction, that is, no contraction between the clips, although there was visible contraction of the circular muscle proximal to the point of stimulation. Attempts were then made to localize the areas of receptivity to stimuli or, in other words, to determine in what portions of the graft movements could be elicited by stimulation at any given point. By the simple expedient of shifting the recording clips and using one unit at a time, it was possible to demonstrate that either muscle coat responds only to stimuli within a definite zone. This area is termed the irritation zone.

A. Localization of Stimuli Necessary to Produce Contraction of the Longitudinal Muscle: The points of stimulation are best shown by means of the upper diagram in figure 8. Circles indicate attachments of the clips in different positions, while the connecting lines show the position of the stimuli. *A, B, C* and *D* represent the positions of the recording clips, while *C, L* and *R* indicate the center and the left and right portions, respectively, of the graft. With the clips at *A* and *B*, stimuli were applied between *A* and *B*, *B* and *C* and *C* and *D*, not only at the center of the graft but at each margin. Thus, for each position of the clips stimuli were applied at nine points. The procedure was then repeated with the clips at *B* and *C* and finally at *C* and *D*. The results are shown in table 2 and graphically in figure 9.

It is therefore obvious that a stimulus applied to the intestinal mucosa below, or distal to, the point which is recorded elicits no contraction of the longitudinal muscle above the point of stimulation. Stimulation at or above the point of record produces strong contractions at and below the area of stimulation which decrease in magnitude as the distance from this area increases. In the three portions of the table it is shown that stimuli applied along the longitudinal plane in which the recording clips are attached produce contraction only if they

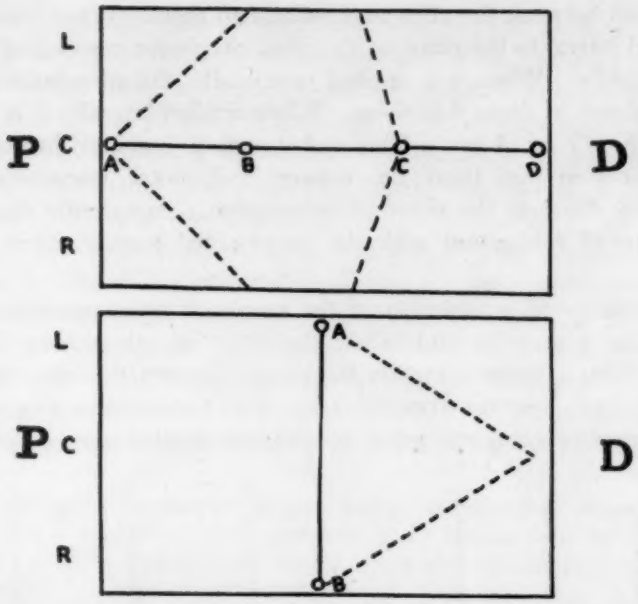

Fig. 8.—Schematic representation of the graft taken from the colon. *P* represents the proximal end; *D*, the distal end; *R*, the right side; *L*, the left side and *C*, the center. The solid line with circles represent the attachment of the clips of the recording instrument. Further details are given in the text. With the clips attached at *B* and *C*, as shown in the upper diagram, stimuli within the area enclosed by the broken lines are effective in eliciting a contraction of the longitudinal muscle. With the clips at *A* and *B*, as shown in the lower diagram, stimuli within the area of the isosceles triangle with the base *A-B* and the broken lines are effective in eliciting a contraction of the circular muscle between *A* and *B*.

TABLE 2.—*Effect on Contractions of the Longitudinal Muscle Coat of an Intestinal Graft of Stimulation of Various Points of the Mucosa (Fig. 8)*

Position of Stimulus	Effect	Position of Stimulus	Effect	Position of Stimulus	Effect
		Recording Clips Attached at A and B			
AB–L	Moderate contraction	BC–L	No contraction	CD–L	No contraction
AB–C	Strong contraction	BC–C	No contraction	CD–C	No contraction
AB–R	Moderate contraction	BC–R	No contraction	CD–R	No contraction
		Recording Clips Attached at B and C			
AB–L	Moderate contraction	BC–L	Moderate contraction	CD–L	No contraction
AB–C	Strong contraction	BC–C	Strong contraction	CD–C	No contraction
AB–R	Moderate contraction	BC–R	Moderate contraction	CD–R	No contraction
		Recording Clips Attached at C and D			
AB–L	Weak contraction	BC–L	Moderate contraction	CD–L	Moderate contraction
AB–C	Moderate contraction	BC–C	Strong contraction	CD–C	Strong contraction
AB–R	Weak contraction	BC–R	Moderate contraction	CD–R	Moderate contraction

are applied between the clips or proximal to them. When the stimulus is applied lateral to the plane of the clips, the motor response diminishes rather rapidly. When it is applied proximally, the stimulus is effective for a distance of from 4 to 6 cm. When applied laterally it is effective only within 2 or 3 cm. This reflex action becomes intelligible on the assumption that there are sensory and motor nerve connections which run distal to the point of stimulation. Apparently the mucosa has no nerve connection with the longitudinal muscle above its own level.

To summarize, stimulation of the mucosa causes contraction of the longitudinal muscle at and below the point of stimulation, but none above. With a linear stimulus the area of contraction may be represented by an isosceles triangle (fig. 8). Conversely, a given area of the intestine contracts when stimuli are applied above it. Such a

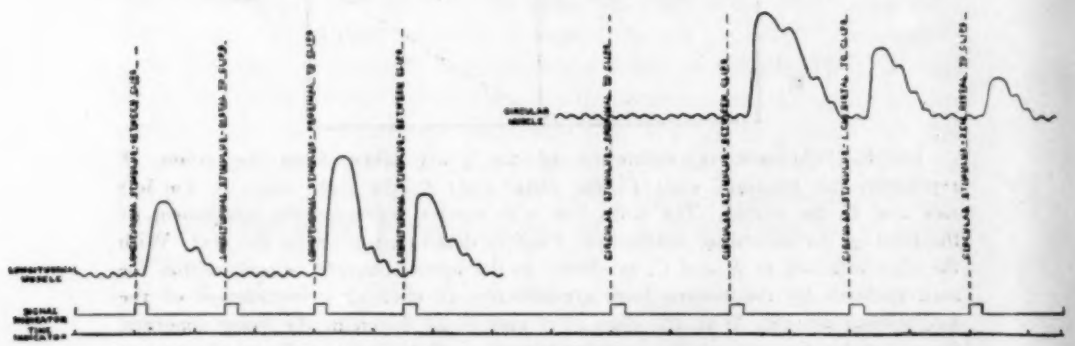

Fig. 9.—Results of stimulation of the colon at different positions on the contraction of the longitudinal and the circular muscle. Stimulation of the distal part produces no contraction of the longitudinal muscle, while stimulation of the proximal portion produces no contraction of the circular muscle.

stimulus acting alone would cause an increase in the diameter of the intestinal lumen below the point of stimulation.

B. Localization of Stimuli Necessary to Produce Contraction of the Circular Muscle: The lower diagram in figure 8 shows the position of the clips on the graft and the points of stimulation. The clips were attached at *A* and *B*. Stimuli were applied at points 2 and 4 cm. on either side of the center. The results are shown in table 3 and graphically in figure 9.

It is at once obvious that the circular muscle responds to stimuli in a manner different from that of the longitudinal muscle. All stimuli proximal to the clips are incapable of eliciting contraction between the clips. Stimulation between or distal to the clips, on the other hand, elicits contraction which varies inversely as the distance from the point of stimulation. When stroke stimuli are applied trans-

versely, both muscle coats respond with contraction, with that of the circular muscle predominant, as already described. It may therefore be assumed that there are sensory and motor nerve connections which run proximal to the point of stimulation. The mucosa appears to have no nerve connections with the circular muscle below its own level.

The characteristics just described have been noted in all three portions of the bowel tested, although not as distinctly in the jejunum and ileum. An interesting variation was noted in the jejunum. While there was no immediate contraction of the circular muscle distal to the point of stimulation, evidence of activity could be seen several seconds later. If watched closely this contraction could be seen to pass downward from the initial contraction in the manner of a peristaltic wave. If the distance was measured between the point of stimulation and the recording clips when placed distally, the speed of the wave could

TABLE 3.—*Effect on Contraction of the Circular Muscle of an Intestinal Graft of Stimulation of Various Points of the Mucosa (Fig. 8)*

Position of Stimulus	Left	Center	Right
	Recording Clips Attached at A and B		
Proximal to clips			
4 cm.	No contraction	No contraction	No contraction
2 cm.	No contraction	No contraction	No contraction
Between clips	Strong contraction	Strong contraction	Strong contraction
Distal to clips			
2 cm.	Weak contraction	Strong contraction	Weak contraction
4 cm.	No contraction	Weak contraction	No contraction

be determined. It was found to move at the rate of approximately 1 cm. in twenty seconds.

COMMENT

The results obtained in these experiments and the work by one of us (M. G. M.)[1] on pithed cats show beyond any shadow of doubt that stimulation of the vagus nerve or mucosal irritation elicits contraction first of the longitudinal and then of the circular muscle. The result of such a mechanism is to increase the lumen of the intestine and then to decrease or obliterate it. These experiments offer no suggestion that either muscle coat is at any time actively inhibited by mucosal stimulation. If a balloon system is used as a recorder, the effect, i. e., the contraction of the longitudinal muscle below the point of stimulation followed by spasm of the circular muscle above, may be interpreted as inhibition (increase in volume of the intestinal lumen) followed by stimulation. The fallacy of such an observation has already been pointed out.

1. Mulinos, M. G.: Proc. Soc. Exper. Biol. & Med. **29**:186, 1931.

The results obtained by a more careful study of the locus of stimulation and the region of response point definitely to the existence of a myenteric reflex. The sequence of events is somewhat as follows: A stimulus (bolus) at any point along the intestine elicits contraction of the longitudinal muscle at and below that point. The lumen is enlarged to permit reception of the bolus. A few seconds later there is contraction of the circular muscle at and above the point. The lumen is thereby constricted, forcing the bolus onward. These phenomena are graphically illustrated in figure 10.

The phenomenon is a true reflex, for it is abolished both by cocainization and the injection of atropine sulfate systemically. It is a true myenteric reflex, for it does not depend on any connection with the paravertebral sympathetic ganglions. All that can be said at present is that this myenteric reflex occurs in intact, unanesthetized dogs. No denervation or purging is necessary (Bayliss and Starling,[2] Cannon [3] and Alvarez [4]). It is possible that the localized stimulus if continued

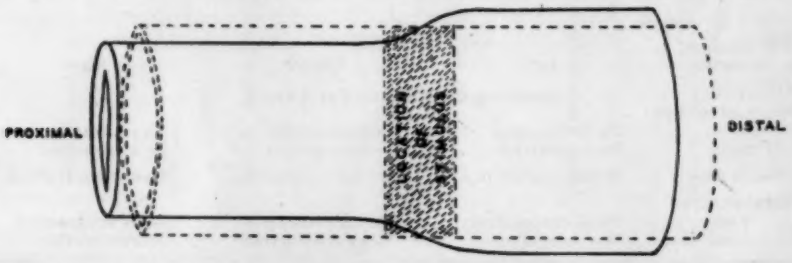

Fig. 10.—Graphic representation of the law of the intestine: When the stimulus (bolus) is applied in the shaded area, the longitudinal muscle contracts proximal to the point of stimulation and the circular muscle distal to the point, with the results explained in the text.

downward along the intestinal mucosa would result in a chain reflex, giving the appearance of peristalsis. No such studies have as yet been made.

It has already been mentioned that the mucosa is functionally connected with the two muscular coats in a characteristic manner. Sensory nerves (afferent) connect the mucosa with the longitudinal muscle at and below its own level and with the circular muscle at and above the same level. Further, impulses to the longitudinal muscle become manifest more quickly than impulses to the circular muscle. It is impossible to say at this time whether the difference in the rate of response is to

2. Bayliss, W. M., and Starling, E. H.: J. Physiol. **24**:90, 1899.
3. Cannon, W. B.: Am. J. Physiol. **30**:114, 1912.
4. Alvarez, W. C., and Mahoney, L. J.: Am. J. Physiol. **69**:211, 1924. Alvarez, W. C., and Starkweather, E.: ibid. **47**:293, 1918.

be found in the afferent fibers of the nerves or in the circularly arranged muscle fibers. It may be that in the case of the longitudinal muscle fibers the afferent nerves have their endings and, presumably, the source of acetylcholine or other such hormones (Mulinos, 1929) very near the parasympathetic myoneural junctions of the muscle. The quickness of response is, then, a function of the rate of diffusion of the *Vagusstoffe* into the cell. On the contrary, the smooth muscle cells of the circular coat may lie at a greater distance from the nerve endings, giving a response which is slower than that of the longitudinal muscle by the time necessary for diffusion into the cell. This same delay in transit exposes the acetylcholine to the destructive action of the esterase, so that less of the drug reaches the cell. Such a concept may explain the observation that longitudinal stimulation of the mucosa of the colon rarely elicits contraction of the circular muscle, while transverse stimulation produces contractions in both coats. The intestinal mucosa may be pictured as made up of a mosaic of sensory nerve receptors. These are arranged in rows of pairs, one member of each pair to the circular muscle and the other to the longitudinal muscle. On longitudinal stimulation a large number of pairs are stimulated, but only a few of the endings send fibers to any one set of circular muscle fibers. The little acetylcholine which is liberated near the circular muscle is destroyed by the esterase before it can reach the cell, and there is no contraction. When the stimulus is applied transversely, there is much more response because the number of impulses to the muscle is many times the number arising from longitudinal stroking. The longitudinal muscle fibers respond to both types of stimulation because they are situated nearer their corresponding nerve endings. We believe that the sensory elements of the myenteric reflex persist after the graft has been separated from the central nervous system.

ACTION OF DRUGS

The next phase of experimentation is concerned with the action of certain drugs on the exteriorized bowel. While the work is not complete at present, several interesting results have been obtained. To avoid ambiguity these will be discussed in groups.

Morphine Group.—That morphine causes strong contraction with "splinting" of the bowel is commonly accepted. By means of the exteriorized graft the mode of its action can be easily demonstrated. Thus, it was seen that when morphine was injected subcutaneously there followed after a latent period of from thirty seconds to two minutes a gradual spastic contraction of the circular muscle, which usually reached its height after from one or two minutes and was maintained for more than an hour. This effect was constant but varied in degree

at different times and in different animals. Coincident to the contraction of the circular muscle the longitudinal muscle was inhibited, the recording lever falling far below the base line and remaining there until after the contraction of the circular muscle had ended. If the mucosa was stimulated by mechanical means during this period there was no change of tone. There was, however, an exaggerated excursion of the minor rhythmic contractions coincident to the spastic change, which maintained the established oscillatory frequency.

A mixture of the hydrochlorides of the opium alkaloids similarly injected in proportionate doses produced a similar result. Papaverine, on the other hand, produced no effect, regardless of the dose administered. Other derivatives of opium have not been tested.

Pitressin Group.—This group includes a number of drugs which are not necessarily related to the extracts of the pituitary gland but which are used clinically for the activation of peristalsis in the presence of paralytic ileus.

No constant effect could be demonstrated by the subcutaneous or intramuscular injection of pitressin, in doses as great as 2 ampules at the time. In one or two experiments strong contraction of the longitudinal muscle was noted, with coincident inhibition of the circular muscle, but since this could not be repeated in subsequent tests its authenticity is to be doubted. If, however, pitressin was injected during the height of a morphine spasm, the circular muscle was invariably released from the effects of the morphine spasm within a few minutes (fig. 11).

Intramuscular injections of solution of posterior pituitary likewise produced no demonstrable changes. Peristaltine, a drug containing the active principle of cascara sagrada, produced no constant or conclusive reaction, nor did a German preparation of an extract of the spleen. Physostigmine salicylate caused an increase in the activity of both muscle coats, resulting in coincidental contractions of moderate magnitude of the longitudinal and the circular muscle, with a slight increase in tone. The activity was greatest between five and twenty-five minutes after injection, but it was not constant or persistent. Acetylcholine likewise resulted in a series of coincident contractions, which lasted for about fifteen minutes and were accompanied by a general increase in irritability to mechanical stimulation.

Other Drugs.—Epinephrine injected intravenously in small doses produced an inconstant major contraction of the longitudinal muscle, beginning from one to two minutes after injection. Larger doses produced subsequent strong and well sustained contraction of the circular muscle. Blanching of the mucosa usually followed the injection of even minute doses in about twenty seconds. Ephedrine, on the other

hand, caused no conclusive activity. Histamine, when injected intramuscularly, produced an increase in the activity of both coats, especially the circular. Like physostigmine salicylate, it increased the irritability of the mucosa to mechanical stimulation.

The effects of atropine have already been mentioned. While it caused no muscular activity in itself, it inhibited all reaction to mechanical stimulation. It did not, however, affect the spastic contraction brought on by morphine, whether administered before or after the latter drug. Cocaine applied topically destroyed the receptivity to mechanical stimuli at the point applied but did not prevent contraction of the muscle at that point if the stimulus was applied elsewhere in a zone sensitive to irritation. Beginning about one minute after application, however, there was marked contraction of the circular muscle, which reached its greatest magnitude about three minutes later and was main-

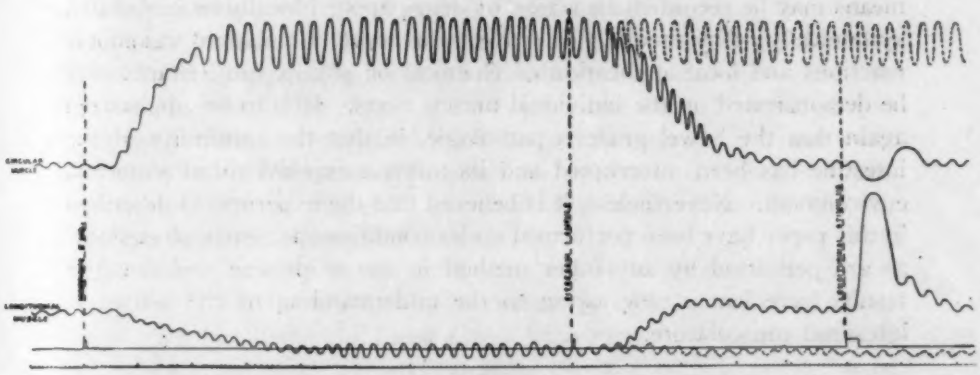

Fig. 11.—Diagrammatic reproduction of the effects of morphine and pitressin on the colon. About two minutes after the injection of morphine the circular muscle begins to contract strongly, with exaggerated excursions of the minor rhythmic contractions, while the oscillatory frequency of the colon is maintained for an hour or more (dotted line) unless pitressin is injected, in which case the bowel is released from the morphine spasm.

tained for thirty minutes or more. Pentobarbital sodium injected intraperitoneally for the production of general anesthesia in no way altered the reaction of the musculature to mechanical stimuli, nor was the tonus in general altered.

It is to be emphasized that the results of the aforementioned experiments on the action of drugs cannot as yet be accepted without reservation, as many are still under way and have not been sufficiently corroborated. The results stated, however, comprise a preliminary report, which will no doubt lend insight into the vast possibilities of experimental work made available by the exteriorized bowel graft.

MISCELLANEOUS STIMULATION

Heat and Cold.—The effect of heat and cold were tested by placing on the mucosa pledgets of cotton on which hot or cold water was allowed to drip. Definite stimulation of the muscle was noted, but the effects were inconstant. In general, however, it may be stated that after the application of heat contraction of the longitudinal muscle predominates, while after the application of cold contraction of the circular muscle is stronger.

Electrical Stimulation.—Electrical stimulation by means of an inductorium invariably resulted in rapid and strong contraction of the circular muscle, without manifestations of activity in the longitudinal muscle.

CONCLUSIONS

Further applications of the method are almost unlimited. By this means may be recorded the action of drugs applied locally or introduced systemically or by mouth. The effects of nerve stimulation, vasomotor reactions and local application of chemical or physiologic irritants may be demonstrated on the individual muscle coats. It is to be emphasized again that the bowel graft is pathologic, in that the continuity of the intestine has been interrupted and its mucosa exposed to an abnormal environment. Nevertheless, it is believed that the experiments described in this paper have been performed under conditions as nearly physiologic as are permitted by any other method in use at present and that the results have lent a new aspect to the understanding of the action of intestinal musculature.

VARIATIONS OF THE CRANIAL VENOUS SINUSES IN THE REGION OF THE TORCULAR HEROPHILI

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I. TYPES OF VARIATION

Le Double [1] has stated that to "describe one by one all the variations in the venous sinuses is impossible, and if it were done today, it would be incomplete tomorrow." Anatomically that may be true, but the variations of surgical interest, especially in the torcular region, may be definitely ascertained. It has long been recognized that the major volume of venous blood is directed through the right lateral sinus, whereas the straight sinus usually directs its major volume into the left lateral sinus. This right-sided predominance of the venous outflow from the brain was recognized at an early date by both Hunauld [2] and Morgagni.[3] For the sake of brevity, the evidence of right-sided predominance noted in studies of the skull, the jugular foramen and the dura has been summarized in table 1.

Just why the right lateral sinus should develop to carry the greater volume of blood in the majority of persons is still a moot point. Von Meyer,[4] Smith,[5] Bluntschli [6] and Zeiger [7] have sought in turn to explain this primary variation. From a perusal of their papers one is forced to the unsatisfactory assumption that it is a part of phylogenetic development. It is due perhaps to differences in channels of outflow and per-

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From the Department of Surgery, Johns Hopkins Hospital.

1. Le Double, A. F.: Traité des variations des os du crâne de l'homme et de leur signification au point de vue de l'anthropologie zoologique, Paris, Vigot frères, 1903.

2. Hunauld, P.: Hist. acad. roy. d. sc. Paris, 1730; cited by Le Double.[1]

3. Morgagni, J. B.: Adversaria anatomica omnia, Lugd. Bat., J. A. Langerak, 1741, vol. 6, p. 132, plate I, fig. 1.

4. von Meyer, H.: Die Sinus transversus des Hinterhauptbeins, Arch. f. Anat. u. Physiol. (Anat. Abt.) **1**:271, 1877.

5. Smith, E. G.: On the Asymmetry of the Caudal Poles of the Cerebral Hemispheres and Its Influence on the Occipital Bone, Anat. Anz. **30**:574, 1907.

6. Bluntschli, H.: Ueber die Asymmetrie der Sinus transversi durae matris bei Mensch und Affe, Verhandl. d. Gesellsch. deutsch. Naturf. u. Aerzte **2**:361, 1908.

7. Zeiger, K.: Ueber die Ursachen der Asymmetrie der Sinus transversi und sigmoidei beim Menschen, Beitr. z. Anat., Physiol., Path. u. Therap. d. Ohres. **19**:184, 1922-1923.

haps to intracranial asymmetry that has been in turn influenced by asymmetrical growth of the extremity.

Five general types of variation of the sinuses are theoretically possible in the region of the torcular Herophili:

1. Common pool type. This is the classic and textbook picture of conformation of the sinuses and is actually encountered far less often

TABLE 1.—*Direction of Venous Outflow from the Brain as Noted in Studies by Various Authors*

Cases	Author	Date	Right	Left
Skull				
	Hunauld [2]	1730	+	0
14	Morgagni [3]	1741	+	0
100	Rüdinger, N.: Beiträge zur Anatomie des Gehörorganes, der venösen Blutbahnen der Schadelhöhle, sowie der überzähligen Finger: II. Ueber den Abfluss des Blutes aus der Schädelhöhle, Munich, Lit.-Artist Anstalt (T. Riedel), 1876	1876	71	27
512	Sperino, G.: Circolazione del capo. Rapporto fra la circolazione endo ed extracraniana, Torino, Camilla & Bertolero, 1884.	1884	269	78
100	von Spee, in von Bardeleben, K.: Handbuch der Anatomie des Menschen, Jena, Gustav Fischer, 1896, vol. 1.	1896	68%	13%
200	Le Double [4]	1903	137	29
400	Sturmhöfel, O. A.: Ueber die Eminentia cruciata des Hinterhauptbeines, Königsberg i Pr., O. Kümmel, 1903	1903	232	61
	Zieger [7]	1923	60-70%	0
Jugular Foramen				
126	Theile, F. W.: Ztschr. f. rat. Med. **6**: 227, 1855.	1855	46	24
100	Rüdinger	1876	71	27
449	Korner: Ztschr. f. Ohrenh. **19**: 322, 1889.	1889	264	109
530	Budde, K.: Ueber Dehiscenzen in der unteren Wand der Paukenhöhle, Göttingen, W. F. Kaestner, 1891	1891	40-64%	26-30%
	Zuckerkandl, E., in Schwartze, H.: Handbuch der Ohrenheilkunde, Leipzig, F. C. W. Vogel, 1892	1892	54-60%	25-30%
Dural Preparations				
50	Dumont, J. N.: Les sinus postérieure de la dure-mère et le pressoir d'Herophile chez l'homme, Thèse de Nancy, no. 1, 1894.	1894	75%	
35	Henrici and Kikuchi [9]	1903	43%	
42	Mannu, A.: Internat. Monatschr. f. Anat. u. Physiol. **24**: 304, 1907	1907	60%	
60	Vernieuwe [12]	1920	43%	
	Zeiger [7]	1923	66-68%	
35	Pfeiffer [13]	1930	60%	
50	Edwards [10]	1931	24	21
24	Gibbs, E. L., and Gibbs, F. A.: Anat. Rec. **59**: 419, 1934.	1934	+	

than are the other patterns noted here. In this variation the longitudinal and the straight sinus meet in a more or less common pool from which the blood is directed to the lateral sinuses. The latter are ordinarily equal but may vary in size within narrow limits.

2. Plexiform type. This is the type of variation of the sinuses that should be expected from the bilateral embryologic development of this

region as detailed in the studies of Streeter.[8] Many subtypes are possible, but there is usually adequate intercommunication between the lateral sinuses. The longitudinal and the straight sinus may each be divided into two divisions, equal and unequal, and the lateral sinuses may be equal in size but usually are moderately dissimilar. The straight sinus may be divided into two branches, equal and unequal, with the longitudinal sinus single, the latter flowing usually to the right with the smaller half of the straight sinus, or this may be reversed. The longitudinal sinus may be divided into two equal or unequal branches with the straight sinus single, the latter usually flowing to the left side with the smaller branch of the longitudinal sinus. There is generally more pronounced difference in the size of the lateral sinuses in these last two subtypes.

3. Ipsilateral type. In this type the longitudinal sinus runs to one side, usually the right, and the straight sinus to the opposite side. Circulation between the lateral sinuses, if present, must take place through an additional direct channel or through the formation of a foramen, both types varying considerably in size. In the majority of cases the lateral sinus on the side of the longitudinal sinus flow will be much the larger.

4. Unilateral type. In this extremely rare conformation both the longitudinal and the straight sinus empty into one lateral sinus. The opposite sinus may be attenuated, being fed only by minute venous channels in the adjacent dura, or it may be completely absent.

In all the aforementioned general variations, the occipital sinus plays a minor rôle in the formation of the variation and in the task of conveying the outflowing volume of blood. It may be absent or extremely small.

5. Occipital type. The last main type of variation of the sinuses is directly concerned with the occipital sinus when it is of sufficient caliber to be of value in carrying blood. The commonest variation in the adult is the persistence of a large single or paired occipital sinus with large marginal sinuses, comparable to the pattern that is so common in the fetus or during the first few years of life. The second rare occipital abnormality is that in which either the longitudinal or the straight sinus or both in a common pool formation empty directly into a large occipital sinus at the expense of one lateral sinus, which will be found to be attenuated.

All these types, with the exception of 3 and 5, have been more or less aptly described by writers on this subject. Their findings are summarized in table 2.

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8. Streeter, G. L.: Development Alterations in the Vascular System of the Brain of the Human Embryo, Contrib. Embryol. **8**:5, 1918.

ANATOMIC STUDIES

The dural preparations were obtained from one hundred consecutive autopsies performed in the pathologic service of the Johns Hopkins Hospital. All specimens were excluded that had been involved in operative procedures. One was from a patient with thrombosis of the basilar sinus with the lateral sinuses secondarily involved and one from a patient with direct thrombosis of the lateral sinus. Five were from patients who had undergone cerebral trauma and seven from patients with cerebral

TABLE 2.—*Types of Variation of the Sinuses Noted by Various Authors*

Author	Date	Cases	Common Pool, Percentage	Plexiform, Percentage	Ipsilateral, Percentage	Unilateral	Occipital
Dumont, J. N.: Les sinus postérieure de la dure-mère et le pressoir d'Herophile chez l'homme, Thèse de Nancy, no. 1, 1894	1894	50	8	80	12 ?	0	0
Henrici and Kikuchi [9]	1903	35	11	77	12 ?	0	0
Mannu, A.: Internat. Monatschr. f. Anat. u. Physiol. **24**: 304, 1907	1907	42	4	68	28	0	0
Vernieuwe [13]	1920	60	42 ?	28	30 ?	1 case	1 case
Pfeiffer [12]	1930	50	26	60	5 ?	0	0
Edwards [10]	1931	50	12	48	36	4%	0
Lieutaud, J.: Essais anatomiques: Précis de la médecine pratique, Paris, Vincent, 1761	1761	..	..	..	..	1 case	
Hallett, C. H.: M. Times **17**: 50, 1848	1848	..	..	..	..	1 case	
Henle, J.: Handbuch der systematischen Anatomie des Menschen, Braunschweig, F. Vieweg u. Sohn, 1871	1871	..	..	..	..	Noted	
Sperino, G.: Circolazione venoso del capo. Rapporto fra la circolazione endo ed extra-craniana, Torino, Camilla & Bertolero, 1884	1884	..	..	..	..	..	1 case
Ballance: Lancet **1**: 1057, 1890	1890	..	..	..	..	1 case (skull)	
Sturmhöfel, O. A.: Ueber die Eminentia cruciata des Hinterhauptbiens, Königsberg i Pr., O. Kümmel, 1903.	1903	..	..	..	..	8 cases (skull)	18 cases (skull)
Le Double [1]	1903	..	..	..	..	3 cases (skull)	
Streit [14]	1903	..	..	..	..	..	1 case
Gleason: J. A. M. A. **98**: 379 (Jan. 30) 1932	1932	..	..	..	..	1 case	
Ersner and Myers: Laryngoscope **43**: 800 (Oct.) 1933	1933	..	..	..	..	3 cases (x-ray)	

tumor with operative procedures not destroying the pattern of the sinuses. Fifty-seven of the patients were men, and forty-three, women; forty-nine, white persons, and fifty-one, Negroes. The age incidence by decades was fairly uniform, with a low figure of four in the 61 to 70 year period and a high of nineteen in the 31 to 40 year period. Twelve preparations were secured from infants less than 1 year old. All the material was studied in place in the skull on an average twelve hours after death.

The injection of gelatin or metal with formation of a permanent cast, perfusion estimation and simple dissection have been used by

previous investigators in the study of abnormalities of the sinuses. Since the surgical anatomy of the region of the torcular, with its complex architecture, was of particular interest, it was found by trial and error that careful dissection, with or without previous injection of a colored material, such as india ink, was most trustworthy. In the case of many specimens this technic was amplified and made permanent by sections stained with hematoxylin and eosin. An average of several diameters was used for the relative measurement of sinuses. The sinus pattern was dissected in place or removed in its entirety for section. During this procedure, the markings of the skull were defined in relation to the architecture of the sinuses. Roentgen studies were made of the typical patterns and the rare abnormalities after the injection of a mixture of gelatin, potassium chromate and lead acetate.

Common Pool Type.—Nine instances of this simple type of conformation of the sinus were observed in this series, a number that closely agrees with that given in previous reports. In all but two, the lateral sinuses were equal in size; in these two, the right lateral sinus was slightly larger. A very small occipital sinus entered the pool in three instances; a moderate-sized sinus entered the pool in one. In two a small occipital sinus entered the left lateral sinus within 1 cm. of the pool, and in three no occipital sinus was present. The markings of the skull were practically equal.

Plexiform Type.—There were fifty-six examples of this type of sinus pattern, and practically all the theoretical subtypes were observed. The pertinent details are summarized as follows:

Right lateral sinus greater than left lateral sinus		23
Slightly	15	
Twice	7	
Three times	1	
Left lateral sinus greater than right lateral sinus		7
Slightly	3	
Twice	4	
Right lateral sinus equal to left lateral sinus		26
Longitudinal sinus or greater branch to right		25
Longitudinal sinus or greater branch to left		7
Longitudinal sinus divided equally		24
Straight sinus or greater half to right		8
Straight sinus or greater half to left		27
Straight sinus into torcular		3
Straight sinus divided equally		18
Intercommunication between lateral sinuses		56
Adequate	49	
Slight	7	
Intercommunication between lateral sinuses by combination of direct channel plus a branch of either main sinus		44
Intercommunication by branch of longitudinal sinus alone		8
Intercommunication by branch of straight sinus alone		4
Occipital sinus		
Small		45
Large		3
Absent		5
Abnormal		3
Markings of skull		
Apparently equal		23
Noticeable variation		18
Indefinite markings		13
None		2

The classic pattern of the plexiform type and the various subtypes are noted as follows:

Longitudinal sinus divided equally into two branches; straight sinus divided equally into two branches; right lateral sinus equal to left lateral sinus	9
Longitudinal sinus divided equally into two branches; straight sinus divided equally into two branches; right lateral sinus greater than left lateral sinus	1
Longitudinal sinus divided equally into two branches; straight sinus divided, greater branch to the left; right lateral sinus equal to left lateral sinus	1
Longitudinal sinus divided equally into two branches; straight sinus undivided into left lateral sinus; right lateral sinus equal to left lateral sinus	10
Longitudinal sinus divided equally into two branches; straight sinus undivided into left lateral sinus; right lateral sinus greater than left lateral sinus	1
Longitudinal sinus divided equally into two branches; straight sinus undivided into right lateral sinus; right lateral sinus equal to left lateral sinus	1
Longitudinal sinus divided equally into two branches; straight sinus into midtorcular region; right lateral sinus greater than left lateral sinus	1
Longitudinal sinus divided, greater branch to right lateral sinus; straight sinus undivided into left lateral sinus; right lateral sinus greater than left lateral sinus	9
Longitudinal sinus divided, greater branch to right lateral sinus; straight sinus undivided into left lateral sinus; right lateral sinus equal to left lateral sinus	3
Longitudinal sinus divided, greater branch to right lateral sinus; straight sinus undivided into right lateral sinus; right lateral sinus greater than left lateral sinus	4
Longitudinal sinus divided, greater branch to right lateral sinus; straight sinus undivided into midtorcular region; right lateral sinus greater than left lateral sinus	1
Longitudinal sinus divided, greater branch to right lateral sinus; straight sinus undivided into midtorcular region; right lateral sinus equal to left lateral sinus	1
Longitudinal sinus divided, greater branch to right lateral sinus; straight sinus divided equally into two branches; right lateral sinus greater than left lateral sinus	4
Longitudinal sinus divided, greater branch to left lateral sinus; straight sinus undivided to left lateral sinus; left lateral sinus greater than right lateral sinus	2
Longitudinal sinus divided, greater branch to left lateral sinus; straight sinus undivided to right lateral sinus; left lateral sinus equal to right lateral sinus	1
Longitudinal sinus divided, greater branch to left lateral sinus; straight sinus divided equally into two branches; left lateral sinus greater than right lateral sinus	3
Longitudinal sinus undivided to right lateral sinus; straight sinus divided, greater branch to right lateral sinus; right lateral sinus greater than left lateral sinus	1
Longitudinal sinus undivided to right lateral sinus; straight sinus divided, greater branch to left lateral sinus; right lateral sinus greater than left lateral sinus	1
Longitudinal sinus undivided to right lateral sinus; straight sinus divided equally into two branches; right lateral sinus greater than left lateral sinus	1
Longitudinal sinus undivided to left lateral sinus; straight sinus divided, greater branch to right lateral sinus; left lateral sinus greater than right lateral sinus	1

The plexiform type of sinus pattern illustrates well the tendency toward right-sided predominance, with the larger volume of the longitudinal sinus directed toward the right and the lesser volume of the straight sinus directed toward the left, or opposite, side. In only one instance was there a wide disproportion between the volumes of the lateral sinuses, and in only eleven were there noticeable differences as great as 2 to 1. There are uniformly full channels of cross-circulation at the torcular, through the divided sinuses or through a combination of

these and accessory channels. The place of the occipital sinus in this pattern needs little comment, and the obvious abnormalities will be discussed.

Ipsilateral Type.—This type of sinus pattern was noted in thirty-one preparations and was viewed with particular interest because of the character of its intersinus communication at the torcular. The longitudinal sinus entered the right lateral sinus undivided in twenty-six of these specimens and the left lateral sinus in the remainder. The straight sinus naturally followed the opposite course. The right lateral sinus was equal in volume to the left in fifteen cases, slightly larger in six, twice as large in five, three times as large in one and four times as large in one. The left lateral sinus was slightly larger than the right lateral sinus in two cases and twice as large in one. In 42 per cent of the cases, then, there was a right-sided overdevelopment, frequently of a major character.

The channels of intercommunication of the lateral sinuses at the torcular were of two types, and in no instance were both methods of cross-circulation seen in the same preparation. The first consisted of an oval foramen, sometimes slitlike, connecting the longitudinal and the straight sinus at the torcular as they veered in opposite directions to enter the lateral sinuses. In only one case was this foramen so minute as to be without value as a practical means of cross-circulation. Three foramina were small, measuring from 2 to 3 mm. in diameter, and four were large, measuring from 3 to 6 mm. in diameter.

The second type of cross-circulation seen at the torcular was that of an individual venous channel, uniformly short, the longest measuring 1.3 cm. in length. It usually connected the two sinuses at the right angles they made with the lateral sinuses. In ten preparations this single channel was large, measuring from 3 to 6 mm. in diameter (single in the majority of cases, in two preparations this channel was duplicated); in four it was small, measuring from 2 to 3 mm. in diameter; in seven it was minute, scarcely measurable, and in one all intersinus communication was absent (figs. 1, 2 and 3).

The occipital sinus was minute in ten cases, small in seventeen and absent in two. There appeared no definite tendency for this sinus to enter the longitudinal sinus, the straight sinus or the intersinus channel. There were two major abnormalities of the occipital sinus, which will be noted.

The markings of the skull were of equal intensity in fifteen cases, disproportionate in fourteen and indefinite in two.

The ipsilateral type of conformation of the sinuses shows an increasing percentage of right-sided predominating patterns, with the dispro-

portion increasing in extent as compared with the common pool and plexiform types. Lack of an adequate cross-circulation was noted in eight, or 25 per cent, of the preparations in this group. Henrici and

Fig. 1.—Photomicrograph (8 ×) of a cross-section of the intercommunication between the lateral sinuses at the torcular in the ipsilateral sinus pattern. The arrows indicate the double channel. The large sinus is the occipital.

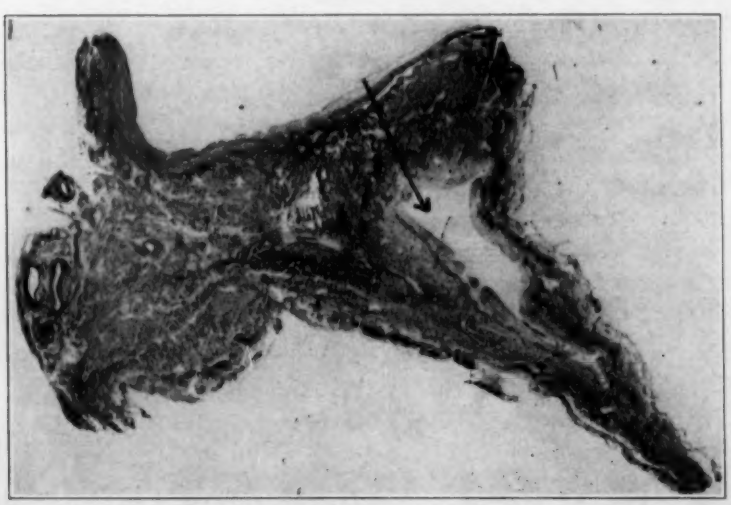

Fig. 2.—Photomicrograph (8 ×) of a cross-section of the intercommunication between the lateral sinuses at the torcular in the ipsilateral sinus pattern. The arrow indicates the single channel.

Kikuchi [9] commented on three cases in which the intercommunication at the torcular was very small, one perhaps lacking, and mentioned eleven in which it was large, attributing little significance to the finding. In the eighteen cases in which Edwards [10] noted the ipsilateral type of conformation, he found "sometimes very little intercommunication." Klestadt [11] stated that lack of intercommunication between the lateral sinuses is a factor in some cases of cerebral back pressure in the course of thrombosis of a lateral sinus. Finally Pfeiffer [12] described one case found in the study of fifty preparations of the dura in which intersinus circulation was effected by a paired occipital sinus of small caliber. With these exceptions, scant attention has been paid to this important variation of the torcular.

Unilateral.—There were four examples of this rare conformation of the sinuses in the one hundred preparations of the dura studied. In three both the longitudinal and the straight sinus entered the left lateral sinus, with the absence of a true right lateral sinus; in one both major

Fig. 3.—Roentgenograms of an ipsilateral sinus pattern, showing: *A*, the "foramen" type of intercommunication at the torcular; *B*, minute direct channel intercommunication at the torcular, and *C*, the "direct channel" type of intercommunication at the torcular. *L* indicates the left lateral sinus; *R*, the right lateral sinus; *X*, the longitudinal sinus, and *S*, the straight sinus.

sinuses entered the right lateral sinus. In one of the unilateral patterns there was superimposed a gross occipital abnormality. The four examples are described in detail.

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9. Henrici, C., and Kikuchi, J.: Die Varianten der okzipitalen Sinusverbindungen (Confluens sinuum) und ihr klinische Bedeutung, Ztschr. f. Ohrenh. **42**: 351, 1903.

10. Edwards, E. A.: Anatomic Variations of the Cranial Venous Sinuses: Their Relation to the Effect of Jugular Compression in Lumbar Manometric Tests, Arch. Neurol. & Psychiat. **26**:801 (Oct.) 1931.

11. Klestadt, W.: Zerebrale Symptomenkomplexe bei otogener Sinusphlebitis, Ztschr. f. Laryng., Rhin. u. Otol. **13**:83, 1924.

12. Pfeiffer, A.: Ueber die Variationen der Sinus der hinteren Schädelgrube besonders des Sinus occipitalis, Ztschr. f. Hals-, Nasen- u. Ohrenh. **25**:503, 1930.

1. The longitudinal sinus entered the left lateral sinus at the torcular undivided, and the straight sinus likewise emptied its entire volume into a quasi common pool formation at the same place. The left lateral sinus was huge, measuring 1.3 cm. at the sigmoid curve. At the torcular there was a minute channel, measuring from 1 to 2 mm. in diameter, which extended laterally, assuming the course and position of the absent right lateral sinus. At the jugular foramen, this sinus measured 4 mm. in diameter, being fed by three small veins in the dura of the right occipital and cerebellar fossae. The occipital sinus was minute and entered the left lateral sinus. There were no markings of the skull on the left side.

2. Both the longitudinal and the straight sinus emptied their entire volumes into the right lateral sinus by means of a quasi common pool formation at the torcular. From each sinus, 1 cm. from its entrance into the pool, a minute channel extended to the left side, the two uniting to assume the position and course of the absent left lateral sinus. At the jugular foramen, this attenuated sinus measured 3 mm. in diameter, being fed by two small veins in the dura of the occipital fossa. The right lateral sinus was huge, measuring 1.6 cm. in diameter. The occipital sinus was absent. There were no markings of the skull on the left side.

TABLE 3.—*Résumé of Abnormalities of the Sinuses*

	1. Predominance of the Lateral Sinus				2. Presence of Major Disproportion Between Lateral Sinuses			3. Presence of Inadequate Cross-Circulation at the Torcular		
Type	Cases	Right-Sided Predominance	Left-Sided Predominance	Equal	Cases	Right-Sided Predominance	Left-Sided Predominance	Small (2 to 3 Mm.)	Minute	Absent
Common pool	9	2	0	7	9	0	0	0	0	0
Plexiform	56	23	7	26	56	8	4	7	0	0
Ipsilateral	31	13	3	15	31	7	1	7	8	1
Unilateral	4	1	3	0	4	1	3	0	0	0
		39%	13%	48%		16%	8%	14%	8%	1%

3. Both the longitudinal and the straight sinus entered the left lateral sinus, the latter at the torcular and the former at a point 2 cm. laterally. From the region of the torcular, two small channels extended to the right side to form an attenuated right lateral sinus, which measured 4 mm. at the jugular foramen, again being amplified by feeder veins from the occipital dura. The occipital sinus was absent. The markings of the skull on the right side were barely visible 2 cm. from the jugular foramen. The left lateral sinus measured 1.6 cm. at the sigmoid curve.

4. Both the longitudinal and the straight sinus entered the left lateral sinus, which measured 1.4 cm. in diameter. From the region of the torcular, a minute channel extended to the right side and assumed the course and position of the right lateral sinus. At the jugular foramen, this attenuated sinus measured 3 mm. in diameter, being fed by small veins in the occipital dura. A paired occipital sinus entered the left lateral sinus 0.5 cm. lateral to the entrance of the major sinuses. The right branch was relatively large, measuring 0.5 cm. in diameter, and without communicating with the left branch it entered the right marginal sinus and thus the right jugular foramen. The left branch of the occipital sinus was minute. There were no markings of the skull on the right side.

Occipital Abnormalities.—There were two general types of abnormality of the occipital sinuses, the first being a preservation of the fetal

pattern in the adult sinus system and the second an exaggeration of the occipital sinus and one marginal sinus, connecting either with the torcular or with either major sinus and aiding materially in the distribution of the volume of blood.

There were two instances of the first type, although less pronounced variations were frequent. Both occipital sinuses were single, dividing normally into the marginal sinuses and then emptying into the jugular foramina. Both, however, measured from 6 to 8 mm. in diameter, being as large in each preparation as the lateral sinuses.

There were four instances of the second general type. One has already been described in the discussion of the unilateral conformation of the sinuses, that is, a paired occipital sinus with one large branch extending from the left lateral sinus adjacent to the torcular to the right jugular foramen. In two cases an occipital sinus measuring from 6 to 8 mm. in diameter extended from the left lateral sinus to the left jugular foramen. Similar cases have been reported by Vernieuwe [13] and Streit,[14] in which in addition there was insufficient cross-circulation at the torcular. In the fourth case the straight sinus directed two-thirds of its volume to the occipital sinus and the remainder to a small lateral sinus. The longitudinal sinus emptied its entire volume into the left lateral sinus.

Abnormalities of the Longitudinal and Lateral Sinuses (Local).—There were two instances of abnormality of the longitudinal sinus adjacent to the torcular, both being evidence of failure to complete the bilateral embryologic anastomosis along the midline of the skull. In one the longitudinal sinus represented a double venous channel from the region of the posterior parietal lobe, about 7 cm. from the torcular. The second was a similar and shorter duplication of the sinus, starting 4 cm. from the torcular.

Two abnormalities of the body of the normal lateral sinus were observed, representing "local migration" changes of embryologic growth. They were noted as small outgrowths of the sinus wall, occurring at the sigmoid curve; abnormalities that have been termed "lateral sinus cloacae" by Ruttin.[15]

SUMMARY

The anatomic literature concerning abnormalities of the venous sinuses of the region of the torcular has been briefly reviewed.

13. Vernieuwe: Les anomalies des sinus de la dura-mène: Leur signification clinique en otologie, Rev. de laryng. **42**:207, 1921.

14. Streit, H.: Ueber otologisch wichtige Anomalien der Hirnsinus, über accessorische Sinus und bedeutendere Venenverbindungen, Arch. f. Ohrenh. **58**: 161, 1903.

15. Ruttin, E.: Kloacken und Blindsackbildung am Sinus sigmoideus, Acta oto-laryng. **9**:217, 1926.

One hundred dural preparations of this region have been studied.

There is from this study anatomic evidence of: (*a*) right-sided predominance in 39 per cent of these specimens and left-sided predominance in 13 per cent, (*b*) major disproportion between the lateral sinuses in 24 per cent, (*c*) inadequate cross-circulation at the torcular in from 10 to 15 per cent, (*d*) a gross occipital abnormality in from 4 to 6 per cent, (*e*) absence of one lateral sinus in 4 per cent and (*f*) direct relationship between the volume of the sinuses and the markings of the skull.

The "normality" of the pattern of the sinus should be defined, it appears, not by its anatomic arrangement, because this may be variable, but by the efficiency of its response to dynamic studies and to pathologic changes within that pattern.

II. VALIDITY OF THE QUECKENSTEDT TEST IN THE DIAGNOSIS OF THROMBOSIS OF THE LATERAL SINUS

Since the application of the Queckenstedt test to the diagnosis of thrombosis of the lateral sinus by Tobey and Ayer,[16] certain observations have been noted that are contradictory to those made in the original studies. These variations from the normal or expected reading fall into three groups.

The first comprises those cases in which a unilateral and false negative Queckenstedt reaction has been obtained in spite of the fact that thrombosis of the lateral sinus has been demonstrated clinically. Canuyt and Klotz [17] reported the case of a 20 year old farmer with a history of chronic otitis media on the right side for fifteen years. Ten days before admission there developed evidence of an acute infection involving the opposite ear, diagnosed as acute mastoiditis. A Queckenstedt test was performed to confirm the presence of thrombosis of the lateral sinus on the left side. In the lateral position, the spinal fluid pressure while the patient was resting was 48 cm. of water. Pressure on the right internal jugular vein caused an elevation in pressure to 80 cm. of water. With pressure on the left internal jugular vein, the manometer reading remained at 48 cm. A purulent thrombosis of the left lateral sinus was evacuated at operation. Twenty-three days after this procedure, a second Queckenstedt study was done. The pressure

16. Tobey, G. L., Jr., and Ayer, J. B.: Dynamic Studies on the Cerebrospinal Fluid in the Differential Diagnosis of Lateral Sinus Thrombosis, Arch. Otolaryng. **2**:50 (July) 1925.

17. Canuyt, G., and Klotz, A.: Quelques considérations sur le signe de Queckenstedt à propos d'un cas de thrombophlébite du sinus lateral opéré et guéri, Rev. d'oto-neuro-opht. **7**:513, 1929.

during rest was 45 cm. of water. Compression of the right internal jugular vein induced a rise to 75 cm.; pressure on the left internal jugular vein caused a rise to 55 cm. of water. Thirty-five days after operation a third Queckenstedt test disclosed a resting pressure of 38 cm. of water. Compression of the jugular vein at this time gave practically equal responses, a rise on the right side to 52 cm. of water, and on the left, or thrombosed side, to 56 cm. Gaillard and Mayoux [18] reported a similar case. The preoperative spinal fluid pressure was 60 cm. of water. Pressure on the internal jugular vein of the affected side produced no response; pressure on the opposite side caused a rise of 17 cm. Later, an abscess of the lateral sinus was evacuated. Similar studies of dynamic changes fifteen days later revealed an elevation in pressure of 7 cm. in water on each side in spite of operative obliteration of the sinus. These observers expressed the belief that contradictory results were obtained because of dilatation of anastomosing venous channels, naming particularly the inferior petrosal sinus, the thyrolingual-facial trunk, the ophthalmic vein and the pterygoid plexus. Recanalization of the sinus appeared improbable in view of the relatively short time involved.

Mayoux [19] observed a third case that confirms this hypothesis. Prior to operation on a thrombosed lateral sinus, elevation of pressure of the spinal fluid on the compression of each jugular vein was of equal magnitude—40 cm. of water. After clinical evidence of extension of this thrombosis to the cavernous sinus, the Queckenstedt test on the thrombosed side caused the pressure to fall to 22 cm., whereas it remained at 40 cm. on the opposite side, indicating a suppression of collateral channels. The further observation of Whitehead [20] illustrates the mechanism of this collateral circulation. A rapid thrombosis of the lateral sinus on one side involved the torcular region. Papilledema developed, but after a tremendous dilatation of the facial, temporal and external jugular veins, the intracranial pressure subsided. Frenckner,[21] Stauffer,[22] Lemaitre and Aubin [23] and Kopetzky [24] have reported identical cases.

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18. Gaillard, R., and Mayoux, R.: Sur l'épreuve de Queckenstedt dans les thromboses sinuso-jugulaires, Rev. de laryng. **48**:700, 1927.

19. Mayoux, R.: L'épreuve de Queckenstedt en otologie: Causes d'erreur; Interpretation des résultants, Rev. prat. d. mal. d. pays chauds **8**:563, 1928.

20. Whitehead, A. L.: A Case of Thrombosis of the Right Lateral Sinus in Which the Clot Extended Beyond the Torcular Herophili, Proc. Roy. Soc. Med. (Clin. Sect.) **2**:60, 1908.

21. Frenckner, P.: Some Experiments with Venosinography: A Contribution to the Diagnosis of Otogenous Sinus Thrombosis, Acta oto-laryng. **20**:477, 1934.

22. Stauffer, N. P.: Difficulties in Diagnosing Lateral Sinus Thrombosis, Ann. Otol., Rhin. & Laryng. **37**:890, 1928.

(Footnotes continued on next page)

Further study with the Queckenstedt test both of patients with acute thrombosis of a lateral sinus and of patients at various intervals after exenteration of the lateral sinus is necessary to evaulate the course of this phenomenon. It is probable, however, that a unilateral falsely negative Queckenstedt response in the course of proved thrombosis of the lateral sinus has for its cause the appearance of a collateral circulation in adjacent cranial sinuses.

The second group embraces those rare cases in which a bilateral positive response to the Queckenstedt test is obtained, although pressure on both internal jugular veins simultaneously produces an adequate response. It is obvious that the amplitude of the rise on unilateral compression of an internal jugular vein is in proportion to the degree of resting pressure. Claude, Lamache and Aubry [25] studied fifty-eight Queckenstedt readings in thirty-four cases. In two normal persons there was no response to pressure on either jugular vein, i.e., a bilateral positive response to the Queckenstedt test, with the resting spinal fluid pressure at a low level. They attributed this false reaction to the inert vegetative nervous systems of these particular persons. Dandy,[26] in the article in which he first described the cerebral Queckenstedt test, described two cases of pertinent interest. In the third patient of his series, a young girl with symptoms of increased intracranial pressure, papilledema and no localizing signs, cerebral and spinal, dynamic studies gave a resting pressure of 140 mm. of water. On compression of either the right or the left internal jugular vein alone, there was no rise in pressure. Simultaneous compression gave a rise to 300 mm. of water. Ventriculography gave negative results. The pattern of the sinuses could not be studied. In the fourth patient, one with a rapidly progressing glioma of the brain stem, exactly similar findings were repeatedly registered. At autopsy, an occipital sinus, larger than either lateral sinus, was found to extend from the torcular to the jugular bulb on the left side. In the studies of variation of the sinuses in the region of the torcular described earlier in this paper, 4 per cent of one hundred dural preparations were found to exhibit a variation similar to that noted by Dandy. In all, there were extensive channels of cross-circu-

23. Lemaitre, F., and Aubin, A.: Le signe de Queckenstedt dans un cas de thrombophlébite compliquée de méningite séreuse, Arch. internat. de laryng. **33**: 974, 1927.

24. Kopetzky, S. J.: An Observation on the Diagnosis of Lateral Sinus Thrombosis Contradictory to the Results of Tobey and Ayer, Arch. Otolaryng. **7**:532 (May) 1928.

25. Claude, H.; Lemache, H., and Aubry, M.: Compression des veines du cou et tension céphalorachidienne, Compt. rend. Soc. de biol. **96**:261, 1927.

26. Dandy, W. E.: Cerebral (Ventricular) Hydrodynamic Test for Thrombosis of the Lateral Sinus, Arch. Otolaryng. **19**:297 (March) 1934.

lation from one lateral sinus to the other, formed by the abnormal occipital sinus. It is probable that the unusual results of dynamic studies reported are due to such a venous pattern.

The third group comprises those instances in which a unilateral positive response to the Queckenstedt test is obtained, although the lateral sinus is not thrombosed and no abnormality of the sinus can be demonstrated. In the first of two cases reported by Gaillard and Mayoux,[18] exploration of the lateral sinus after a positive reaction to the Queckenstedt test revealed a perisinuous abscess obliterating the lumen of the sinus. Pressure on the internal jugular vein on the side of the supposed thrombosis had given an elevation of 2 cm. of water from the resting pressure, and the opposite side, a reading of 23 cm. Gardner [27] reported three cases of tumor of the cerebellopontile angle and one of glioma of the cerebellar lobe in which a positive or highly suggestive response to the Queckenstedt test was found prior to operation. Exploration in each instance disclosed complete or partial obliteration of one transverse sinus by the tumor.

Edwards [28] has pointed out the influence of abnormalities of the cranial venous sinus on the interpretation of readings of spinal fluid pressure. In a review of one hundred and fifty consecutive cases at the Boston City Hospital, he noted that one third of the readings showed differences that were clinically apparent. In one case, no rise occurred on one side, i.e., a positive response to the Queckenstedt test, although no abnormality could be demonstrated clinically. In a second case, pressure on the right internal jugular vein gave a rapid rise to 220 mm. of water and on release of pressure, a prompt fall to 110 mm., the resting pressure. Pressure on the opposite side gave a slow rise to a maximum of 190 mm. and an equally slow fall to the original reading. Paraffin casts of the lateral sinuses made at autopsy disclosed a smaller sinus lumen on the left side. Recent anatomic studies described earlier in this paper have verified the presence of a major disproportion in the size of the lateral sinuses in 24 per cent of one hundred dural preparations and an absence or extreme attenuation of one lateral sinus in 4 per cent of these cases. The following case is the first to be reported which illustrates both the clinical and the pathologic aspect of a completely false positive Queckenstedt reading obtained on the basis of an anatomic abnormality.

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27. Gardner, W. J.: The Tobey-Queckenstedt Test in the Localization of Tumors of the Cerebellopontile Angle, Arch. Neurol. & Psychiat. **20**:585 (Sept.) 1928.

28. Edwards, E. A.: Anatomic Variations of the Cranial Venous Sinuses: Their Relation to the Effect of Jugular Compression in Lumbar Manometric Tests, Arch. Neurol. & Psychiat. **26**:801 (Oct.) 1931.

REPORT OF A CASE

E. R., a white policeman aged 34, was admitted to the accident room of the Johns Hopkins Hospital on March 30, 1934, in a semicomatose, delirious condition. The history was elicited from relatives. The family history was negative. The past history was irrelevant with the following exceptions: He had diphtheria as an infant and scarlet fever at the age of 12 years, followed by a chronic, intermittent discharge from the left ear, without tinnitus or noticeable loss of hearing. He was right-handed. The discharge from this low grade otitis media was sometimes clear and scanty and at other times purulent. There was no history of fever or headache. His present illness developed in the latter part of December 1933, with acute coryza, accompanied by an exacerbation of the aural discharge. He noted intermittent dull generalized headache and easy fatigability. Six weeks before admission, the pain in the head became localized in the left frontal and temporal regions and became severe, throbbing and constant. Five weeks before admission, a sharp pain developed in the left mastoid region, with a blood-tinged, foul-smelling aural discharge. Lavage of the canal of the external ear with a solution of sodium chloride gave no relief. Extraction of a tooth did not relieve the pain. Twelve hours before admission he became nauseated and vomited. His headache became more severe. Six hours before admission he lapsed into a semicomatose state.

Examination.—The temperature was 103 F., the pulse rate 130, the respiratory rate 30 and the blood pressure 140 systolic, 90 diastolic. The patient was well developed and adequately nourished. He was restless, necessitating restraint. He responded poorly to stimuli. The skin was hot and moist; no petechiae were noted. No local or generalized adenopathy was present. The skeleton was normal. The head was essentially normal except for definite tenderness over the left mastoid region, without cutaneous change. There was perforation of the left ear drum, with a purulent discharge. Examination of the fundi disclosed full veins without papilledema. Visual acuity and the visual fields could not be determined. Neurologic examination revealed little except the presence of a slightly stiff neck. The impression was that the condition was acute pyogenic meningitis secondary to mastoiditis and extradural abscess, on the left. The patient was admitted to the neurosurgical service.

Spinal puncture revealed increased pressure. A Queckenstedt test was not made. The fluid was cloudy, with 12,000 cells, practically all polymorphonuclear. The reaction to the Pandy test was one plus. No organisms were seen in a smear. Culture was later reported as negative.

The condition remained the same. No localizing signs of cerebral abscess were noted. Twelve hours after admission operation was performed—simple mastoidectomy and drainage of an extradural abscess on the left side. A culture was reported later as showing a heavy and pure growth of Bacillus proteus.

Preoperative Queckenstedt Test.—In the lateral position, a resting pressure of 200 mm. of water was noted. With pressure on the right internal jugular vein, a rise of pressure to 300 mm. of water occurred. With pressure on the left internal jugular vein, slight if any elevation was noted. Pressure on both internal jugular veins simultaneously caused a pressure of 360 mm. of water. The fluid was turbid, with 18,000 cells, all polymorphonuclear. No organisms were present in a smear. Culture was later reported as negative.

Postoperative Course.—High unremitting fever persisted, with profuse drainage from the mastoidectomy incision. The patient remained restless and delirious. The pulse rate gradually fell, the patient assuming a state of relative bradycardia.

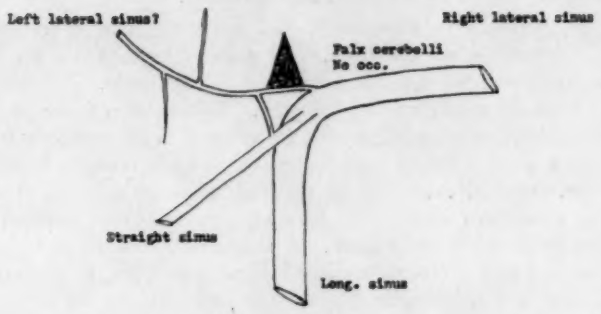

Fig. 4.—Diagram of the unilateral sinus pattern. No occipital sinus was present.

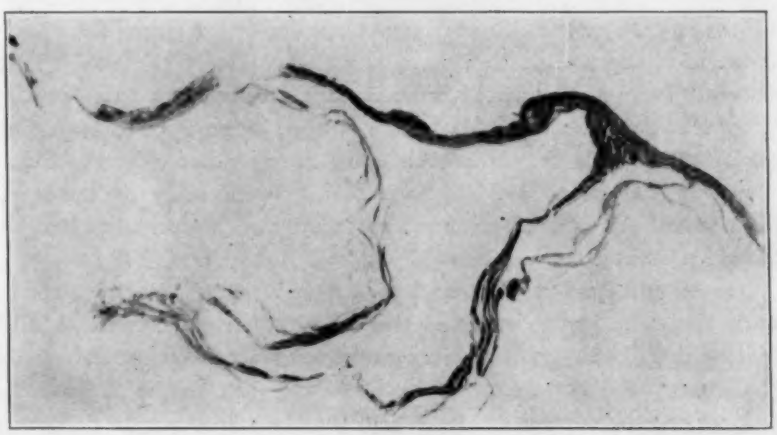

Fig. 5.—Cross-section (8 ×) of the right lateral sinus at the sigmoid curve.

Fig. 6.—Cross-section (8 ×) of the attenuated, or "substitute," left lateral sinus at the sigmoid curve.

On the fourth postoperative day definite right hemiplegia became evident. Death occurred while he was being prepared for operation.

Autopsy Report.—Acute mastoiditis had occurred, and operation had been performed. Perforation of the dura, was present, with acute meningitis. An abscess was present in the left temporal lobe of the brain. Lobular pneumonia was noted. Chronic urethritis was present. Dissection of the cranial venous system showed both the longitudinal and the straight sinus emptying into the right lateral sinus in a quasi common pool formation at the torcular. From each sinus, at a point 1 cm. from its entrance into the pool, a minute channel extended to the left side. An attenuated sinus, thus formed, represented in position and course the left lateral sinus, which was absent. It measured 3 mm. in its longest diameter at the jugular foramen. The right lateral sinus was huge, measuring 1.6 cm. in diameter. There was no occipital sinus. Markings of the skull were absent on the left side, whereas the course of the right lateral sinus was marked by the usual bony groove in the occipital bone (figs. 4, 5, and 6).

SUMMARY

The clinical course, studies of the dynamics of the spinal fluid and the pathologic changes in a case in which a completely positive but false unilateral Queckenstedt reaction was exhibited are recorded. This type of irregularity of the Queckenstedt reaction, when applied to the diagnosis of thrombosis of the lateral sinus, may be due either to external pressure on the sinus walls or to a major abnormality of the sinuses, as illustrated in this case. Such an anatomic abnormality has been reported present in 4 per cent of cranial sinus patterns.

Two other types of irregularity of Queckenstedt reaction, the unilateral false negative and the bilateral false positive, are discussed. They may have their common origin in channels of collateral circulation, either preexistent in the latter type or brought into play in the presence of a thrombosis in the former.

A REVIEW OF UROLOGIC SURGERY

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KIDNEY

Anomalies.—Campbell [1] said that, in the main, anomalies of the upper part of the urinary tract are significant because (1) the renal reserve is diminished, (2) the kidney is misplaced or malformed, (3) there is urinary obstruction, or (4) there is abnormal discharge of urine. In 193 of 282 infants and children with hydronephrosis whom he observed in series the condition was secondary to an anomaly of the upper part of the urinary tract (a frequency of 68.8 per cent). In 179 of 580 young persons with persistent pyuria whom he observed in series 206 anomalies of the upper part of the urinary tract were demonstrated (a frequency of 30 per cent).

The surgical importance of agenesia, aplasia or fused formation of solitary kidney is that the only functioning parenchyma may be unwittingly excised. Congenital ectopic kidneys, as distinguished from abnormally mobile organs, are firmly held in position by an anomalous vascular supply which makes it impossible to elevate them. Reduplication of a kidney permits resection when only half of the reduplicated organ is diseased. Half a kidney, usually capable of supporting life by itself, is preserved. Polycystic kidney in a child is seldom recognized during life, and unless infection, hematuria, stone or obstruction demands

1. Campbell, M. F.: Surgical Treatment of Anomalies of Upper Urinary Tract in Children, J. A. M. A. **106**:193 (Jan. 18) 1936.

intervention, the patient is best let alone; meanwhile, he should be treated as though he had nephritis. If profuse hematuria cannot be checked by blood transfusion or by intrapelvic injection of a 5 per cent solution of silver nitrate, or if there is extreme renal pain, nephrectomy or puncture of the large cysts must be considered. The mortality from nephrectomy is approximately 50 per cent, and that from nephrotomy 30 per cent, within the first postoperative month. In general, the patient lives longer if surgical treatment is not employed. If a large solitary renal cyst is present, the kidney should be resected unless the entire organ is destroyed. For advanced unilateral disease in horseshoe kidney heminephrectomy by division of the organ through the isthmus is the treatment.

Occasionally, the insertion of the ureter into the renal pelvis is unusually high, giving rise to the formation of a spur valve at the ureteropelvic junction. Unless mobilization of the ureteropelvic junction and high suspension of the kidney afford normal drainage, the ureter should be reinserted low in the pelvis to permit dependent drainage. Excision of the spur valve is not satisfactory. Nephrectomy is frequently necessary. An ectopic opening of the ureter requires surgical treatment only if the renal segment drained by the ectopic orifice is diseased or if the anomaly produces incontinence. Although a single ureter may have an ectopic orifice, it is usually the ureter from the upper pole of a reduplicated kidney that has the abnormal opening. In most instances this portion of the organ is diseased. When the ureter involved is single and the kidney is worth saving, transplantation of the ureter into the bladder is indicated. When the ureter with the ectopic opening is from a reduplicated kidney, ureteroheminephrectomy is usually indicated. A ureter with a blind ending is significant if the ureter and pelvis are converted into a cystic mass. The mass may simulate an abdominal tumor. Excision is the treatment; this may require nephrectomy or ureteroheminephrectomy. In the absence of superimposed infection, congenital stricture of the ureter seldom produces scarring. There is narrowing of the lumen of the ureter comparable to the congenital narrowing not infrequently seen in the intestinal tract, the bile duct and the urethra. Congenital stricture of the ureter is most common at the ureterovesical junction or the ureteropelvic junction and in the body of the ureter, respectively. Stricture of the ureter was demonstrated in 101 of 580 children with chronic pyuria. If mild, stricture at the ureterovesical junction may be dilated by bougies passed through a cystoscope. In infants, this dilation must usually be performed by the passage, side by side, of two, three or more no. 4 French catheters. Stricture of the body of the ureter will usually respond to cystoscopic dilation. Rarely the stricture is inflammatory

and surrounded by periureteral sclerosis; the liberation from this may enhance the results of instrumental dilation. Plastic operations on the body of the ureter for stricture can scarcely be expected to be successful. Stricture of the ureteropelvic junction in children commonly produces early hydronephrotic destruction of the kidney, which demands nephrectomy. Occasionally, the lesion is bilateral.

Congenital kinks of the ureter are rare. The kink is almost always found where the ureter leaves its peritoneal attachment to reach the kidney.

Only those aberrant vessels which compress the ureter are significant. If such vessels are present they will almost certainly run to the lower pole from the renal artery or vein, from the aorta or vena cava or from the common iliac artery or vein.

O'Conor [2] said that the more universal adoption of routine urologic examination has demonstrated that anomalies of the upper part of the urinary tract are not only common but often the underlying cause of obstruction and infection. In operation on a solitary kidney, it is important to minimize the operative trauma and to provide free urinary drainage; it is often advisable to decapsulate the kidney. The double ureter, either complete or incomplete, is the most frequent anomaly seen clinically. O'Conor's records show 32 incomplete and 9 complete duplications of the ureter. Two of the complete duplications were bilateral, with four ureteral orifices in the bladder. It has been his experience that the pathologic changes have been situated in the lower segment of the kidney in about 90 per cent of the cases. The upper half of the solitary kidney does not seem to be subjected to obstructive lesions as often as the lower half. Heminephrectomy is an established surgical procedure if half of the solitary kidney possesses a good function. O'Conor has performed this operation in 9 cases, without complication. Complete excision of the ureter, if it is incompletely duplicated, must accompany heminephrectomy. If complete duplication of the ureter is present, the ureter may be treated as it is in ordinary nephrectomy.

Tumors.—Smith [3] reported a series of 40 cases of tumor of the upper part of the urinary tract. There were 16 of hypernephroma, 10 of adenocarcinoma, 7 of carcinoma, 2 of fibrosarcoma, 1 of leiomyosarcoma, 3 of papillary epithelial carcinoma and 2 of tumor in which there was no report, either because the tissue was too necrotic or because the tumor was not removed.

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2. O'Conor, V. J., in discussion on papers by R. Gutierrez, A. B. Hawthorne, M. F. Campbell and G. J. Thomas and J. C. Barton, J. A. M. A. **106**:199 (Jan. 18) 1936.

3. Smith, G. G.: Neoplasms of the Kidney and Ureter: A Report of Forty Cases, Am. J. Surg. **30**:130 (Oct.) 1935.

The epithelial tumor of the renal pelvis and ureter resembles that of the bladder. It may occur as papilloma, which is apparently benign but which may recur in malignant form. The incidence of epithelial tumor of the renal pelvis as compared with carcinoma of the kidney itself is said to be 1 to 11. The epithelial tumor metastasizes freely; the liver, lungs and bones are frequently affected. The papillary type often metastasizes along the ureter and into the bladder.

The relation of trauma to renal tumor has not been definitely established. The majority of patients give no history of trauma, but occasional cases are reported in which one may suspect a relationship. One case of this type was found in this series; three months before the initial mass and hematuria were noticed, the patient was injured by the caving in of a ditch. Several ribs on the side on which the tumor developed were broken.

The symptoms of renal tumor may be learned from a study of the 40 cases in this series. The first symptom in 26 cases was hematuria, in 14 pain, in 5 loss of weight, in 3 a palpable mass, in 3 digestive disturbance, in 1 irritability of the bladder and in 1 chills and fever. The cause of pain is not always the same. Some patients have a constant dull ache, which may be attributable to hydronephrosis, to pulling on the renal pedicle or to involvement of nerves by the growth. Sharp colicky pain is probably caused by the passage of clots through the ureter. It is usually referred to the renal region on the affected side, but it may be felt in the hypogastrium or even in the thigh. At the time of entering the hospital, 33 patients in the series (82.5 per cent) had a palpable mass in the renal region. The rate of growth of renal tumors unquestionably varies widely, but there is evidence that it may be slow. In this series there were 2 patients who were seen by Smith four and nine years, respectively, before they finally came to operation.

The operability of renal tumors is frequently an open question. In the first place, the existence of metastasis should be determined so far as may be possible. Roentgenograms should be made of the skull, long bones, thorax, lumbar vertebrae and pelvis. If a large tumor of the kidney is covered with a network of veins the size of lead pencils, hemorrhage is more satisfactorily controlled by the transperitoneal approach than it is by the lumbar approach. The lumbar incision should be used for the removal of a small tumor and when the diagnosis is uncertain. The initial incision for transperitoneal nephrectomy consists of an anterior median incision from the xiphoid process to the umbilicus. The peritoneal cavity should be explored, and the kidney should be palpated; if nephrectomy is decided on, a transverse incision, extending from the umbilicus at right angles to the first incision, is carried outward on the affected side as far as the tip of the twelfth rib. Exposure of the

kidney is aided by a sandbag or pillow placed beneath the lower thoracic and upper lumbar vertebrae.

In 3 of the 40 patients in this series, the kidney was explored but was not removed. Nephrectomy was performed in 32 patients, in 21 by the transperitoneal route and in 11 by the lumbar approach. Resection of the twelfth rib proved an aid in several patients in whom nephrectomy was performed by the lumbar approach. There were 7 operative deaths in the entire series, a mortality of 17.5 per cent. Two patients died within a few days of shock, and another patient died of bronchopneumonia. Three patients from whom kidneys were not removed died in less than four months after operation. Of the 30 remaining patients, 4 who had intra-ureteral growths died of recurrence; 2 died of disease of the heart one and two years, respectively, after operation, and 4 died apparently of recurrence. The latter patients lived from one month to eight years after operation. The average length of life was less than two years. Of the 10 patients who are living and apparently well, 2 have survived for one year, 2 for a year and a half, 1 for two years, 1 for three years, 1 for five years, 1 for eight and a half years, and 2 for ten years, a survival of 25 per cent. On the basis of this limited series, hypernephroma offers the best prognosis of any of the malignant tumors of the kidney.

Nichols [4] presented 4 cases which demonstrate the difficulties of making a correct diagnosis of epidermoid carcinoma of the pelvis of the kidney. The average age of the patients was 48 years. Two of the patients were women. Two were men. Hematuria was present in all. Renal calculus was present in 2 patients, and pyonephrosis was noted in the other 2. Palpable masses were present in 2. Three of the patients gave histories of pain, and 1 had had a previous injury. There were no clinical findings which in any way might be considered to be characteristic of epidermoid carcinoma. Roentgenologic examination was made in all the cases. In the first case a definite diagnosis of tumor of the kidney was made from the appearance of the organ in the stereoscopic roentgenogram of the urinary tract. This was the only definite evidence of tumor, and it demonstrated that the palpable mass was connected with the kidney. In the second case the presence of a growth of the kidney was also determined by pyelography, which revealed a tumor of the pelvis of the kidney and invasion of the renal cortex. This was interpreted as carcinoma of the kidney. In the third case the roentgenologic examination was of no aid in determining the presence of carcinoma of the kidney because of the large calculi in the affected kidney. A diagnosis of calculus pyonephrosis was made. In the fourth

4. Nichols, B. H.: Squamous-Cell Carcinoma of the Kidney, Radiology **25**:152 (Aug.) 1935.

case pyelographic findings indicated that tuberculosis of the pelvis of the kidney was present; however, eleven months later another pyelogram established the diagnosis of carcinoma of the kidney. In none of these cases was epidermoid carcinoma of the pelvis of the kidney suspected, and only after microscopic study of the tumor was this diagnosis made.

One case illustrates the presence of squamous cell carcinoma of the kidney in the presence of large calculi of the kidney associated with inflammation and leukoplakia. Such findings should suggest the possibility of the presence of this type of tumor at the time of examination. In this instance there was a history of an injury which might have been significant as an etiologic factor. The large multiple calculi may be considered as the logical contributing factor because of the irritation and the leukoplakia produced. Cure was not obtained in 3 of the cases reported, which indicates the necessity for early diagnosis. In the fourth case, in which examination of the specimen removed at operation revealed early squamous cell changes, the patient was alive two years after operation. Roentgenologic examination of the thorax should always be made when a tumor of the kidney is suspected. Metastasis to the thorax occurred in 50 per cent of these cases.

According to Silverstone,[5] pelvic new growths form from 5 to 7 per cent of all renal tumors; they may be divided into (1) benign papillomas, (2) papillary epitheliomas and (3) flat or alveolar carcinomas. The last group includes the squamous cell carcinoma, or epidermoid.

The squamous cell carcinoma of the renal pelvis is twice as common in males as it is in females. As elsewhere, it arises from epithelium that has undergone metaplasia as the result either of infection or of chronic irritation, usually from stone. There are two types. One type invades the renal parenchyma early and replaces the kidney. The other type obstructs the ureteropelvic junction so that there is hydronephrotic atrophy, without invasion of the parenchyma. Both types metastasize early and widely. There is no tendency toward implantation in the lower part of the urinary tract, as with papillary tumors.

Because the squamous cell growth is frequently associated with renal calculus, there is usually a history of long continued renal disease with increase in the severity of the symptoms marking the onset of neoplasia. Hematuria occurs in about 50 per cent of the patients. The diagnosis of squamous cell carcinoma of the renal pelvis carries with it a hopeless prognosis; the average duration of life is between ten and eleven months. Silverstone reported a case in which carcinoma was not associated with calculus or with infection.

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5. Silverstone, Maurice: Squamous Cell Carcinoma of the Renal Pelvis: Report of a Case, Brit. J. Surg. **23**:332 (Oct.) 1935.

Calculus.—Winsbury-White [6] said that in about 15 per cent of the cases renal lithiasis is bilateral. Such cases present a special problem because of the impairment of both kidneys and because the tendency to recurrence is greater.

It is not uncommon to find a disparity in the size of the calculi; there may be a large branched stone on one side and a small one on the opposite side. It is assumed that the smaller one is of more recent origin, and that lithiasis in one kidney predisposes to disease in the opposite one. This is supported by the facts that there is a greater incidence of bilateral lithiasis late in life, and that in unilateral disease removal of the calculus is very infrequently followed by the formation of one in the opposite kidney.

It is characteristic of large branched bilateral calculi that they do not cause pain until late in the disease. They produce little obstruction at the ureteropelvic junction because of fixation of the limbs in the calices, which prevents the stone from sinking into the outlet of the renal pelvis. When there is marked disparity in size, it is usually the smaller stone which causes pain and obstruction, calling attention to the disease.

Each case presents its own problem of treatment because of the variations in the size of renal stones, in the degree of renal function that remains and in the severity of the infection. Winsbury-White considered the treatment of the various conditions encountered in 36 cases which he observed. In general, he concluded that both kidneys should never be operated on at the same time. Operation on both kidneys carries a mortality of about 50 per cent. The better side should be operated on first, so that if, when operation is performed on the other side, there is some factor which indicates nephrectomy, one is better able to decide whether such a procedure is feasible.

In the presence of large branched bilateral stones, no intervention is advisable unless there is some complication, such as obstruction, pyonephrosis or perinephritic abscess. Under these circumstances, permanent nephrostomy not only relieves the acute condition but improves function, relieves infection and prevents recurrence.

When there is great disparity in the size of the stones, the side with the small stone should be operated on first because of the greater likelihood of obstruction and resulting anuria on that side.

According to Gray,[7] Leriche and Policard contended that in the presence of hypercalcemia deposition of calcium takes place in con-

6. Winsbury-White, H. P.: Bilateral Urinary Calculus, Brit. J. Urol. **7**:235 (Sept.) 1935.

7. Gray, J.: The Effects of Obstruction of the Urinary Tract, with Particular Relation to the Formation of Stones, Brit. J. Surg. **23**:451 (Oct.) 1935; The Effect of Experimental Interference with the Blood-Supply of the Kidneys, with Particular Reference to the Formation of Stones, ibid. **23**:458 (Oct.) 1935.

nective tissue of low metabolism if the blood supply is diminished. To test this theory in relation to the formation of renal calculi, Gray conducted the following experiments: In 40 rabbits the blood supply to one kidney was reduced by ligating one of the two terminal branches of the renal artery. Twenty of these rabbits received a normal diet and the remaining twenty received a diet to which lime and concentrated extract of vitamin D were added in sufficient quantities to produce hypercalcemia. It was found that the latter diet markedly increased the amount of calcium in the urine and diminished the amount of phosphate relatively or absolutely.

Under these circumstances it was found that no stones were formed in the normal kidneys in either group, but that stones occurred in the damaged kidneys of 15 per cent of the rabbits which received the normal diet and of 45 per cent of those which received the diet to which calcium and vitamin D had been added. The stones were large and were always found in the pelvis or calices, never in the parenchyma. The urine was cultured each time that an animal was killed, and only in an occasional one was any infection shown to be present. There was nothing to suggest that this played any part in the pathologic changes.

Histologic studies of the kidney in which stones were formed revealed marked desquamation of the epithelium of the renal pelvis and frequently, if not always, deposition of calcium in relation to the damaged regions and around the desquamated epithelium.

Ten rabbits were fed oxamide in addition to their normal diet, after preliminary ligature of a vessel in one kidney. In 1 rabbit definite stones were formed in the normal kidney, while in 5 rabbits stones were formed in the kidney with the ligature.

The truth of the theory of Leriche and Policard is demonstrated by the results in this series of experiments. The two important factors in the production of a calculus seem to be (1) a dietetic factor, for instance, a calcium-phosphorus imbalance or an excess of some foreign substance such as oxamide, and (2) the local factor which leads to the precipitation of the substances which form the stone.

In view of the fact that the stones always formed in the pelves or calices, it seems that a cavity is necessary. There was always some abnormality of the epithelial lining, and frequently the stones could be demonstrated forming around desquamated epithelium. This suggests that an important factor in the formation of a stone is an alteration in the epithelium which might act by producing variations in surface tension or, more directly, by giving rise to desquamation, the dead epithelial cells then acting as a nucelus for the stone.

With another group of animals, Gray conducted the following experiments to determine the relation of obstruction in the urinary tract to the formation of stones: In 36 rabbits one ureter was ligated so as to produce complete obstruction, and in 4 rabbits one ureter was ligated so as to produce partial obstruction. Twenty-five of the rabbits received a normal diet, and the remaining ones, including those with partial obstruction, received a diet to which calcium and vitamin D had been added in order that hypercalcemia might be produced. Stones were not formed in any of the normal kidneys or in any of the kidneys in which there was complete obstruction. However, in the 4 rabbits which had partial ureteral obstruction and which received the diet containing additional calcium and vitamin D stones formed in the kidney on the obstructed side. It appears from this that there is no tendency toward the formation of stones (even in animals which receive a diet that predisposes to the formation of stones) when renal function is almost entirely absent.

Sisk and Bunts [8] reported 5 cases of nephrolithiasis in which the calculi developed after severe injury to, or disease of, the bone. In 1 case the stones were composed mainly of magnesium phosphate, and in 3 cases, chiefly of calcium phosphate with some calcium carbonate. There seemed to be a definite relationship between renal calculi made up of a phosphate (usually calcium phosphate) and skeletal decalcification. This is attributed to the excessive excretion of calcium salts and other salts that occurs from bones through the kidneys. Spontaneous dissolution and passage of these calculi occasionally occur. Diets with an acid base and acidifying drugs, such as ammonium chloride, increase the elimination of calcium through the kidneys, increase the acidity of the urine and may be beneficial in preventing the formation of calculi of this type.

Tuberculosis.—Addison [9] said that tuberculosis of the kidney, apart from the miliary type, is among the rarer manifestations of the disease of childhood, and comparatively few instances have been observed in children in the first decade of life. Miliary tuberculosis of the kidney is frequently disclosed at necropsies on children who died of tuberculous meningitis or of general tuberculosis. During a period of one year Addison saw tuberculosis of the kidney in 10 children; 7 had other active lesions, usually of the spine or hip. The youngest child was 4 years of age.

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8. Sisk, I. R., and Bunts, R. C.: Spontaneous Dissolution of Renal Calculi, Tr. Am. A. Genito-Urin. Surgeons **28**:149 (June) 1935.

9. Addison, O. L.: Tuberculosis of the Kidney in Childhood, Brit. M. J. **2**:565 (Sept. 28) 1935.

In the earliest stages of invasion of the kidney by tubercle bacilli there are no symptoms; the only sign is slight pyuria, which is usually intermittent and discoverable only on microscopic examination. Hematuria is generally the first objective symptom; this usually is slight and frequently is present only for twelve or twenty-four hours. The hemorrhage recurs at intervals and is associated with increasing pyuria; in the later stages, when there is general involvement of the bladder, hematuria is usually a constant symptom. The urine is acid and, until the disease is well advanced, is seldom contaminated with other organisms.

Diagnosis depends on finding the tubercle bacilli in the urine. In the presence of unexplained chronic or intermittent pyuria a careful examination for this organism should be made. The bacillus is difficult to find in the early stage of infection, and it often is present only intermittently. In the early stage, before there are clinical symptoms, such as constant pyuria and increased frequency of micturition, the disease progresses slowly; it may last many months or even years before general involvement of the kidney occurs.

The child who shows the early stages of infection should be treated in a sanatorium, preferably, at first, in bed. One in whom the disease is advanced and unassociated with other active lesions, should be submitted to nephrectomy provided that no tubercle bacilli are found on catheterization of the ureter of the other kidney and that renal function is within normal limits. If the second kidney is infected and pyelography shows that the lesion is small and the function is satisfactory, nephrectomy may be advisable. The prognosis after the kidney has been removed is favorable. Of 5 of Addison's patients in whom nephrectomy was performed, 3 recovered rapidly and showed the urine free from tubercle bacilli in two or three months. The youngest patient was 9 years old. Two of the patients who survived had been in the advanced stage of the disease. One had had severe involvement of the bladder.

Actinomycosis.—Kretschmer and Hibbs[10] said that actinomycosis of the kidney is rare in infants and children. A survey made by Sanford and Voelker of 670 cases of actinomycosis in the United States revealed only 45 in children. The kidney was one of the least frequent sites of the disease. Edwards, in his review of cases of juvenile actinomycosis, said that in 50 per cent it occurred in the region of the head or neck, in 20 per cent in the thoracic viscera, and in an equal number in the abdomen.

Actinomyces bovis is a facultative anaerobe which is rather easily cultured. On a solid medium it penetrates typically below the surface.

10. Kretschmer, H. L., and Hibbs, W. G.: Actinomycosis of the Kidney in Infancy and Childhood, Tr. Am. A. Genito-Urin. Surgeons **28**:93 (June) 1935.

It is readily killed by heat. The actinomycetes which are derived from vegetable sources are aerobic. Actinomyces bovis has been obtained only from animal sources and probably lives on the mucosa of the mouth and digestive tract. Edwards concluded that it is a normal inhabitant of the secretions of the mouth and gastro-intestinal tract of man and animals, but that in certain instances it may be carried into the tissues, where it is able to establish itself. When the fungus is present in the mouth and gastro-intestinal tract, its implantation into the tissues may be favored by trauma, disease and accompanying organisms. While the actinomycetes of vegetable origin are not identical with that which causes actinomycosis among human beings, trauma of the buccal mucosa may be a factor in producing disease from their presence.

In the treatment of unilateral renal actinomycosis, nephrectomy is the operation of choice unless there is also extensive involvement of other organs. As in renal tuberculosis, the absence of disease in the other kidney must be established by careful study of the urine and by pyelography. Various treatments have been suggested for the operative wound, such as leaving it open and packing it with iodoform gauze. Medical treatment after nephrectomy has been recommended, and the drugs that have been most widely used are potassium iodide and copper sulfate.

Carbuncle.—Graves and Parkins [11] described carbuncle of the kidney as a circumscribed multilocular abscess of the renal parenchyma involving varying amounts of the substance of the organ. It is probably metastatic in most instances, and usually arises from a primary focus of infection elsewhere in the body. The causative organism is most frequently Staphylococcus aureus. The clinical interest in this lesion relates to its relative rarity and to the difficulties in diagnosis.

An analysis of the 66 previously reported instances of renal carbuncle together with the case reported by Graves and Parkins revealed that the disease usually follows a primary staphylococcic infection of the skin. Forty-two of the patients had furuncles, carbuncles or other superficial abscesses. The respiratory tract was the apparent primary focus in only 4 of the patients; 2 patients gave histories of trauma in the region of a kidney, and 1 had had chronic pyelitis. Forty-one of the patients were males, and 25 were females; in 1 instance, the sex was not given. Three of the patients were infants. Two of the latter were 8 weeks of age. One was 9 months old. The time between the original superficial infection and the onset of the illness of the kidney varied from a few days to many months, the average being fifty-three

11. Graves, R. C., and Parkins, L. E.: Carbuncle of the Kidney, Tr. Am. A. Genito-Urin. Surgeons **28**:41 (June) 1935.

days. The onset of the carbuncle of the kidney was marked by pain in the general region of the flank. This was the initial symptom in 46 of the cases. That the pain was not definitely placed or well localized was evidenced by the difficulty in diagnosis, as shown by the fact that there was an average delay of sixty-one days before proper treatment was instituted in 42 of the cases. Malaise, progressive prostration and fever, which often persisted for many weeks, were associated with the pain in most of the cases. Chills were frequently reported, and signs of pleuritic irritation were not uncommon. There was tenderness in or near the kidney in almost every case. Inflammatory changes extending through the diaphragm often resulted in misleading signs in the thorax, on the affected side. Incision and drainage were performed on 19 of the patients, with a mortality of 31.5 per cent; nephrectomy was performed on 39, with 7 deaths (17.9 per cent); the end-results in 2 patients were not given. Removal of the carbuncle from the kidney by enucleation was performed satisfactorily in 5 patients, all of whom recovered.

Roentgenographic and clinical evidences of fixation of the diaphragm on the affected side are of marked diagnostic significance. Often, particularly on the left side, if there is marked infection in or around the kidney, there is a direct extension of the inflammation through the diaphragm, which results in its limitation or fixation as well as in confusing signs and symptoms in the adjacent lung and pleura. When such evidences are present fluoroscopic as well as roentgen examination of the thorax should be made.

The treatment of renal carbuncle is surgical. The earlier and more accurate diagnosis of a suppurative process within the kidney may result in the more prompt use of surgical treatment. The choice of procedure will vary with the condition of the patient. There are three methods of treatment: (1) incision and drainage followed by nephrectomy if necessary, (2) primary nephrectomy and (3) enucleation of the carbuncle. The lowest mortality in this group of cases was obtained with the last-named procedure. The next lowest mortality (17.9 per cent) followed nephrectomy, and, in general, this should be the treatment of choice. Nephrectomy in two stages is valuable if the patient has become seriously depleted by the infection.

Hydronephrosis.—Wilder and Doolittle [12] reported a case of gigantic hydronephrosis in which the kidney contained more than 6 liters of fluid. The kidney was successfully removed. Papin used the term "gigantic" to describe hydronephrotic kidneys which fill a large portion of the abdomen. He referred to cases of hydronephrosis of long

12. Wilder, W. O., and Doolittle, L. H.: "Gigantic" Hydronephrosis, J. Urol. **34**:356 (Nov.) 1935.

standing in which the kidneys contained 30 liters and 36 liters of urine, respectively, and to the case reported by Glas, in which the kidney gave up 30 gallons (110 liters) of fluid at necropsy. Papin also mentioned the cases which recently have been reported by Baldwin, by Auscherlik and by Mosny, Javal and Dumont. In the case reported by Baldwin, the kidney of a child who was 1 year of age contained 2,500 cc. of fluid. Auscherlik found 5 liters of fluid in the kidney of a child aged 3, and Mosny, Javal and Dumont found 30 liters of urine in the kidney of a woman aged 25. Hahn reviewed the literature and reported 2 additional cases, that of a boy aged 8 who had 4 liters of fluid in the right kidney and that of a child whose right kidney contained about 2 liters of fluid. Papin said that the majority of patients in whom enormous hydronephrotic kidneys develop are children or young persons. Occasionally, such kidneys occur in older persons. J. Van D. Young recorded a case in which a woman 38 years of age was operated on for a cyst of the right ovary and was found to have hydronephrosis of the right kidney, from which more than 8 quarts (30 liters) of fluid was removed.

Howze [13] said that giant hydronephrosis is of infrequent occurrence. A review of the literature over a period of twenty-five years revealed only 32 cases. The size of the hydronephrotic kidney varied. In an infant the kidney contained 900 cc. of fluid, and in another patient 50 liters of urine was removed by abdominal paracentesis. Thirty of the patients were operated on; 1 patient died following repeated abdominal paracentesis, and the condition of another was diagnosed at necropsy. Nephrectomy was performed by the transperitoneal route in 11 patients.

Howze reported a case in which the diagnosis was made by cystoscopic study and pyelography. The significant features in this case were: (1) the enormous size of the renal pelvis; (2) the relatively few symptoms over a long period; (3) the fact that a hydronephrotic kidney of such caliber retained a third of the function of a normal kidney, as shown by the specific gravity of the urine and the amount of urea excreted by the affected kidney, and (4) the fact that a satisfactory pyelogram was obtained with a small quantity of opaque medium. Following the removal of 1,000 cc. of fluid from the affected kidney by ureteral catheterization, 50 cc. of skiodan was injected. A roentgenogram revealed an enormous hydronephrotic sac which extended from the diaphragm to the bony pelvis and which crossed the median line and overshadowed a large portion of the outline of the opposite kidney. The patient continued to have some discomfort, and, later, 2,300 cc. of fluid was removed. There was complete relief from

13. Howze, C. P.: Giant Hydronephrosis: Report of a Case, Tr. Am. A. Genito-Urin. Surgeons **28**:1 (June) 1935.

abdominal symptoms until the time of the patient's sudden death from cerebral thrombosis, four weeks later.

Pseudohydronephrosis.—Crabtree [14] said that pararenal pseudohydronephrosis is a rare disease. If the condition is neglected, renal destruction and death may ensue. Its characteristic symptom is continued disability. Discomfort after improvement from renal injury may reasonably be expected to occur; this may be followed at some later date by exacerbation of symptoms, after which renal tumor appears. Hematuria may be absent; if present, it is usually of short duration. An increase in temperature is not to be expected, and fever is usually low or absent during the quiescent stage of the disease. It may be more marked during exacerbation of symptoms and rapid growth of the tumor. The leukocytic count is usually low. Even in the latent stage the disease is debilitating.

Three factors which are necessary for the production of the disease are (1) trauma or perforation which opens the calix, pelvis or ureter within the fatty capsule of the kidney, (2) maintenance of the opening beyond the normal healing period and (3) acquired or preexisting obstruction of the ureter. The disease is rapidly destructive to the kidney. Preservation of the kidney depends on early recognition of the condition and relief of the ureteral obstruction. Separated fragments of tissue of the kidney are usually not sufficiently viable to allow reparative procedures to be employed at some later time after the injury. Repair of the lesion is indicated if the condition has been present for a considerable time.

Treatment by drainage or paracentesis will not be satisfactory except in cases in which the renal damage has been sufficient to produce autonephrectomy. In most instances in which the condition has been present for a long time nephrectomy is necessary. This operation is not always possible because of the fibrous wall of the sac, which may enclose the major portion of the kidney and its pedicle. Demonstration of urine in the sac or of an opening into the renal pelvis is necessary to distinguish the disease from serous cysts.

Trauma.—Turton and Williamson [15] reported a case of rupture of a congenital solitary kidney and reviewed 4 similar instances collected from the literature. Their patient was a boy aged 12 years who had fallen off a gate and landed on his left flank. His chief complaints were pain in the left loin, vomiting and hematuria. The abdomen was rigid, and there was impaired resonance on the left side which increased

14. Crabtree, E. G.: Pararenal Pseudo-Hydronephrosis with Report of Three Cases, Tr. Am. A. Genito-Urin. Surgeons **28**:9 (June) 1935.

15. Turton, J. R. H., and Williamson, J. C. F. L.: Traumatic Rupture of the Congenital Solitary Kidney, Brit. J. Surg. **23**:327 (Oct.) 1935.

to absolute dulness in the flank. His condition improved so that one week after the injury the urinary output was 1,200 cc., the urine was clear, and the area of impaired resonance had receded into the flank. However, on the eleventh day anuria and pain in the left lower abdominal quadrant were noted, and the patient's general condition became worse. An incision was made in the left flank, and a large amount of urine and some clots were evacuated from the extraperitoneal tissue below the left kidney. The patient died on the operating table.

Necropsy disclosed a rupture of the left kidney which extended from the lower pole to the pelvis. There was a congenital absence of the kidney, adrenal gland and ureter on the right side.

In each of the 4 other instances of traumatic rupture of a congenital solitary kidney reported in the literature the right kidney was absent, but the absence was not suspected and a left nephrectomy was performed.

The necessity for determining whether or not a second functioning kidney is present in every case of renal injury is obvious. The best method is excretory urography. When this is not possible and when operation is made urgent because of severe hemorrhage, palpation of the contralateral kidney through the opened peritoneum is imperative before nephrectomy is done. If the ruptured kidney is proved to be a solitary kidney, the operative measures are limited to conservative suturing or partial nephrectomy to arrest hemorrhage.

Colston and Baker [16] presented a series of 13 cases in which clinical examination or operation revealed definite pathologic changes either in the kidney or in the perirenal tissue. The patients had been injured severely in the region of the kidney at varying intervals of time before they appeared for examination. The relationship of the trauma to the conditions described was definitely established in each case; the lesions encountered in these cases varied from those causing minimal disability to those causing complete incapacity.

There must be complete familiarity with the changes that may occur in the kidney or perirenal tissue as late results of injuries to the kidney and the necessary steps taken to prevent their development. When injury to the kidney is suspected the patient should be subsequently studied with special reference to the demonstration of persistent perirenal extravasation. This should be readily recognized as a palpable mass or in the obliteration of the outline of the kidney and psoas shadow on roentgenologic examination. If hematuria has occurred as the result of an accident, an injury to the pelvis or to the calices should be suspected. Subsequent pyelographic studies should be carried out

16. Colston, J. A. C., and Baker, W. W.: Late Effects of Various Types of Trauma to the Kidney, Tr. Am. A. Genito-Urin. Surgeons **28**:171 (June) 1935.

to ascertain that distortion or obstruction has not occurred as a result of formation of scar tissue, since it may lead later to serious damage to the kidney. In the emergency which exists after any suspected injury to the kidney, the surgeon should keep in mind a clear perspective of the ultimate changes that may result.

Extravasation from the Pelvis.—Hortolomei, Ornstein-Streja and Burghele [17] made an intensive experimental study of cases of extravasation from the pelvis of the kidney, and advanced a number of hypotheses with reference to the pathogenesis in these cases. They pointed out that between the pressure of the secretion of the urine and that of its excretion caused by the tonicity and peristalsis of the pelvis there exists a hydrodynamic equilibrium which assures the proper functioning of the excretory apparatus. When this equilibrium is disturbed through increase of intrapelvic pressure, the fluid in the pelvis flows out of its cavity, a phenomenon which is known as extravasation from the pelvis. The fluid thus extravasated nearly always penetrates the kidney and easily enters the venous or the lymphatic circulation, resulting in a pyelovenous or a pyelolymphatic reflux. Extravasation into the tubules is relatively rare in sound kidneys, but overflow into the calices is common.

The pressure necessary to produce rupture into the calices varies from 20 to 80 mm. of mercury; in most cases rupture of the human kidney has occurred at a pressure of from 30 to 50 mm. If the amount of liquid extravasated is small, it remains localized in the sinus of the kidney between the lips of the hilus and forms a sinusal or primary extravasation. But if the reflux continues through the breach it may produce a retroperitoneal, a perivascular or a subcapsular extravasation, all of which can be identified in the respective pyelograms.

The authors indicated the rôle played by extravasation in the production of numerous morbid processes the pathogenesis of which has hitherto been little understood. The production of extravasation by artificial filling of the pelvis has given a great deal of information with reference to clinical extravasation, since it permits the graphic control of the production of reflux and fixes it on the roentgenogram, thus serving as a point of departure in the study of the clinical expression of each type of extravasation.

In a healthy pelvis the production of an extravasation in the course of pyelography produces practically no clinical manifestations except a painful sensation, which is the result of distention. After the production of an extravasation in an infected pelvis the appearance of hematuria following pyelography is often characteristic, and the reflux of the septic content of the pelvis into the renal parenchyma may cause

17. Hortolomei, N.; Ornstein-Streja, M., and Burghele, T.: Les extravasations du bassinet, J. d'urol. **38**:481 (Dec.) 1934.

alarming clinical symptoms, chief among which is a high temperature indicating pyonephritis. It thus may be seen that pyelography is not always a harmless procedure in the presence of an infected kidney, and that it should be used with great caution on any kidney the conservation of which is absolutely indicated. In the same manner, vigorous manipulation of a kidney in the course of nephrectomy for tuberculosis of the kidney may permit the pelvic contents to enter the blood stream and cause postoperative tuberculous septicemia. Another spontaneous pathologic condition which may be the result of excessive pressure within the pelvis of the kidney is acute ureteral obstruction by a calculus, kink or spasm. The colic provoked by any one of these causes often is followed by such symptoms as hematuria, chills and fever, which also may follow artificial distention of the renal pelvis. Thus, the abundant hematuria which in classic theories has been attributed to the lesions caused by the migration of a calculus seems to Hortolomei, Ornstein-Streja and Burghele to be the result of the pyelovenous reflux that occurs during the colic.

Acute pyelonephritis and acute attacks during the course of chronic pyelonephritis may likewise be attributed to massive extension of the kidney due to acute pyelitis through the mechanism of pelvic extravasation, proof of which is found in the histopathologic appearance of the lesions, the suddenness and gravity of the acute attacks and the rapidity of extension of the inflammatory process. In so-called essential hematuria there is, most of all, evidence of the pathogenic rôle played by pyelovenous reflux. The primary cause of such reflux may lie in nephroptosis or ureteral spasm, both of which have been observed repeatedly to be associated with hematuria. Chyluria similarly may follow pyelolymphatic reflux by a mechanism of the same type. Finally, perirenal hydronephrosis and spontaneous perirenal hematoma may be accounted for by the mechanism of perivascular extravasation. The fact that such hematomas repeatedly have been observed to be preceded by violent renal colic inclines the authors to adopt the same pathogenic explanation. After the production of extravasation and pyelovenous reflux the hemorrhage may continue and produce a subcapsular hematoma.

Many of these hypotheses are the result of logical deductions, but since they are based on experimental evidence they should be confirmed by laboratory and clinical study of patients.

Polycystic Diseases.—Goldstein [18] described a new surgical treatment of polycystic kidneys:

> This consists of extraperitoneal exposure of the kidney, freeing the organ, decapsulation where possible, incision and excision of the cysts, nephrostomy,

18. Goldstein, A. E.: A New Surgical Procedure for Treatment of Polycystic Kidneys, J. Urol. **34**:536 (Dec.) 1935.

nephropexy, the establishment of a temporary nephrocutaneous non-urinary fistulous tract, and finally the subsequent puncturing of reformed or large cysts. When the abdominal route is employed . . . a pararectus high Gibson incision is made down to the peritoneum. The peritoneum is then pushed medially, exposing the kidney with its fatty layers. It is then freed laterally on each side. The true capsule is incised lengthwise, opening some of the cysts. Numerous large cysts are then opened, excising the walls of many of them. As many as possible of the cysts are drained. After this procedure the kidney cortex is then split from one pole to the other. . . . With the kidney split, more cysts are drained with the needle and syringe. Hemorrhage is not marked. The medial half of the longitudinal portion of the kidney is then sutured to all layers of tissue above and medial to it, the peritoneum being pushed downward and inward. The other half of the longitudinal split portion is treated likewise. The wound is closed with interrupted plain catgut sutures.

At the end of operation the kidney is well immobilized, and the split cortical portion is exposed. The split halves are approximated to the skin edges. . . . Laterally, the same situation exists, except that the kidney is not in apposition to the peritoneum. This leaves the organ free so that the cysts may be punctured with a needle and syringe under visualization at will, a procedure which is carried out after healing.

The operation is indicated: when there is gradual reduction in the function of the kidneys with nausea, vomiting, weakness and uremic manifestations; when there is pain due to an increase in the size of the cysts and a consequent increase in the size of the kidneys; when there is hematuria resulting from rupture of the enlarged cysts into the calices with anemia and weakness; as a last resort in the treatment of polycystic disease accompanied with uremia and coma.

The immediate result of this operation in a case reported by Goldstein was reduction in the size of the kidney with relief from pain, nausea and vomiting, which had been present for eight months before the patient sought medical attention. The fistulous tract on the left side was kept open for two and a half months, after which it was permitted to "granulate over." The patient gained 16 pounds (7.3 Kg.) and was so well that he returned to work. Seven months later he began to have pain in the right abdominal region with nausea; the right kidney became larger. Immediately following operation on the right kidney, the nausea subsided. He remained well for several months, and then the pain in the right abdominal region returned. The right kidney was again found to be enlarged. The cysts on the left side were again punctured, with relief from symptoms. Goldstein expressed the opinion that the two operations and the subsequent puncturing of the cysts on the left side saved the life of a patient who was in a desperate condition.

Replacement Lipomatosis.—Lieberthal [19] said that comparative pathologic studies have demonstrated that replacement lipomatosis is an

19. Lieberthal, F.: Perirenal and Peripelvic Fibrolipomatosis: Their Relation to Replacement Lipomatosis of Kidney, Surg., Gynec. & Obst. **61**:794 (Dec.) 1935.

advanced form of peripelvic fibrolipomatosis, which accompanies any chronic suppurative process in the kidney to some degree. This condition is a combination of hyperplasia and fibrosis of the peripelvic fat, occurring in response to chronic suppuration and contracture of the kidney. In the advanced form of the disease, the peripelvic fat appears as though it had undergone an extensive active proliferation and as though it had crowded into the renal substance and produced pressure atrophy and destruction of the latter. Histologic examination of the renal tissue usually reveals pyelonephritic contracture and traces of the preceding suppurative process.

All portions of the pathologic adipose tissue in replacement lipomatosis of the kidney are directly continuous with the remainder of the peripelvic fat, and they are definitely demarcated from the renal tissue proper. The development of replacement lipomatosis depends on the presence in the kidney for a period of years of a chronic low grade suppurative process. The circumstances that tend to maintain such a process are those of long continued incomplete obstruction to the outflow of urine from the renal pelvis. Replacement lipomatosis of the kidney must be distinguished from neoplasms of the perirenal and peripelvic fat, of the fibrous capsule of the kidney and of the renal substance. It should not be confused with liposis, which is an entirely different pathologic entity.

Perinephric Abscess.—Rusche and Bacon [20] said that the significant signs and symptoms of perinephric abscess are pain and tenderness in the costo-iliac space, fever, leukocytosis and roentgenologic findings. Frequently, such an abscess has failed to produce the usual symptoms before operation. Diseases involving adjacent structures have presented all the symptoms and findings of a perinephric abscess. All regional structures must be considered in the differential diagnosis. The operation for this lesion is exploratory. Early operation when perinephric suppuration is suspected is a justifiable procedure.

Rusche and Bacon reported 10 cases in which the condition was diagnosed as perinephric abscess. Operation was performed for perinephric abscess in 9 of these cases. The final diagnoses were: appendical abscess in 2 cases, osteomyelitis of a rib in 1 case, osteomyelitis of a rib and vertebrae in 1 case, osteomyelitis of a vertebra in 1 case, ruptured hydronephrosis in 1 case, ruptured aneurysm of the abdominal aorta in 1 case, retroperitoneal abscess containing a toothpick in 1 case, retroperitoneal abscess following perforation of a cancerous bowel in 1 case. In 1 case no pathologic condition was found.

20. Rusche, C. F., and Bacon, S. K.: Unusual Conditions Simulating Perinephric Abscess with Report of Ten Cases, J. Urol. **34**:504 (Dec.) 1935.

Nephrotomy.—Martin and Bruneton [21] described a simple method of suturing used by Marion to secure hemostasis after nephrotomy. The method, which is known as "perirenal subcapsular encirclement," consists in running catgut of a large size (no. 4) completely around the incised kidney, underneath the capsule, without penetrating the organ itself, by passing the curved needle in and out through the capsule until each catgut thread has encircled the kidney like a gathering string in a garment.

Before beginning this reefing, provisional hemostasis is obtained by means of a compress which is passed, in the form of a loop, under the pedicle by means of a curved clamp. The first catgut thread is inserted, by means of a straight needle, under the lower pole of the kidney, through a buttonhole made in the capsule; the double catgut thread is then basted through under the capsule, the two ends being temporarily left free, one at each margin of the incision. Six catgut threads are similarly drawn around the kidney, about 2 to 3 cm. apart and parallel to one another, until the entire length of the kidney has been so surrounded. One should be careful to avoid the pedicle. The ends are not tied until all the threads have been inserted and until a drain has been placed in the lower third of the pelvis of the kidney; the threads are then drawn together and the ends tied successively in such a manner as to assure perfect coaptation of the two flaps; the threads cannot slip during the reefing, because they are held by their buttonholes. After all the ends have been tied the compress is removed, and the neatly bound kidney is replaced in its bed. Before suturing the lumbar muscles, a few moments should be allowed to elapse in order to make certain that hemostasis is actually complete. If there is any oozing, the insertion of an extra catgut thread will usually stop it.

Marion said that coarse catgut threads will more simply and more easily produce hemostasis equal to that which Lowsley effects with bands of catgut ribbon. They can be drawn tight because of their suppleness, and by pulling all of them progressively and successively there is no risk of their breaking; breaking may occur if an infected kidney is sutured by transfixion. The use of fat to tampon the renal breach has not been found necessary. The principal indication for the method is to secure hemostasis after section of the parenchyma of the kidney for the removal of one or more calculi, especially if infection is present.

Transabdominal Nephrectomy.—Rathbun [22] said that the most common indication for transabdominal extraperitoneal nephrectomy is a large tumor of the kidney. The reasons for this type of approach are the necessity for more room and better exposure, the desirability of an early approach to, and control of, the vascular pedicle, and the impor-

21. Martin, R. H., and Bruneton, Jacques: Un nouveau procédé d'hémostase dans la néphrotomie: Le cerclage sous-capsulaire périrénal, J. d'urol. **39**:550 (June) 1935.

22. Rathbun, N. P.: Transabdominal Extraperitoneal Nephrectomy, Tr. Am. A. Genito-Urin. Surgeons **28**:139 (June) 1935.

tance of securing the pedicle before there is any extensive manipulation of the kidney. The main disadvantage of this approach is the occasional difficulty of keeping the intestines out of the operative field. This sometimes involves a considerable degree of mauling of the intestine with resulting increase in the shock involved at the time of operation and increased likelihood of postoperative ileus with its attending discomfort and risk.

It is Rathbun's belief that when the kidneys are unusually large, particularly if there is excessive enlargement of the upper pole, transabdominal extraperitoneal nephrectomy is so difficult as to be practically impossible of execution. When the kidney is large, if the anterior approach is selected, the transperitoneal route is preferable. In this operation the pararenal fascia is usually automatically separated when the outer leaf of the mesocolon is divided. The colon may then be readily displaced toward the midline. If more room is needed, this can be obtained by rolling the liver downward and inward, which is readily done as an intraperitoneal procedure.

URETER

Calculus.—François [23] said that ureteral calculus is serious since it is able to destroy the kidney rapidly by obstruction, dilation and infection. A roentgenogram and a urogram should be made to determine the exact situation of the stone in the ureter. It is necessary to know definitely that the shadow represents a calculus in the ureter, and it is necessary to determine the dimensions of the stone and the changes which have occurred in the affected ureter and the condition of the associated kidney, that is, whether there is dilation or infection, and the function of this kidney.

François reported a series of 53 cases of stone in the ureter. In 16 (30 per cent) of these cases, the stones were passed naturally after cystoscopic procedures such as insertion of an inlying ureteral catheter, injection of glycerin or oil of cajuput, the use of Livermore's dilator, ureteral sounds and dilating bougies, the use of ureteral forceps and fulguration of the orifice of the ureter. In a case in which there was recurrence of stone it was necessary to perform a ureterolithotomy. Extraperitoneal ureterolithotomy or nephrectomy was performed in 35 cases. Ureterolithotomy was performed in 32 cases, and nephrectomy for pyonephrosis was performed 3 times. Nephrectomy for pyonephrosis resulting from ureteral fistula was necessary in 2 cases. There was no immediate mortality. In 3 cases there was recurrence of ureteral stone. The functional value of the associated kidney, which was deter-

23. François, Jules: Diagnostic et traitement des calculs de l'uretère, J. d'urol. **39**:219 (March) 1935.

mined in 18 cases, varied from no decrease in function to complete dysfunction. The functional improvement after operation was verified in 11 cases. The function returned to normal in 2 cases and showed marked improvement in 6 cases. Infection of the associated kidney was noted in 15 cases; it disappeared spontaneously after removal of the calculus in 3 cases, and after changing the acidity of the urine and the use of urinary antiseptics and pelvic lavage in 3 other cases. It was decreased in 2 instances by the same therapy. In 2 cases there were stones in both ureters.

Obstruction.—Henline [24] reported 66 cases in which the presence of noncalculous ureteropelvic obstruction was proved by operation. The cases occurred in 37 males and 29 females. The average age of the patients was 32 years. The right side was affected in 40 patients, and the left, in 27. Forty-four patients had infection. The complications were nephroptosis in 9 cases, infantile kidney in 1, double kidney in 2, single kidney in 2. In 11 cases the condition was bilateral. The phenolsulfonphthalein test for function of the kidney on the affected side revealed no function in 32 patients, 50 per cent or less of the normal function in 26 and more than 50 per cent of the normal function in 9. This test is inaccurate in determining the function of the renal parenchyma in hydronephrosis. Neither comparative determination of the amount of urea in the urine from the kidney nor intravenous urography gives an accurate index of renal function in hydronephrosis. In most cases, hydronephrosis results from obstruction at the ureteropelvic junction. The cause of the obstruction should be sought while the kidney occupies its normal position in the loin, rather than after it is delivered.

The cause of obstruction found at operation was stricture in 31 cases, aberrant vessels in 29, fibrous bands or adhesions in 18, high ureteropelvic insertion in 6 and a combination of these causes in 17. Palpation of the ureteropelvic junction may reveal increased density from muscular hypertrophy and hence a decrease in the size of the lumen of the ureter, or a stricture.

Nephrectomy was necessary in 45 cases; lysis and severing of the aberrant vessels or fibrous bands, with nephropexy, was done in 16, and plastic operations were performed in 6. The latter type of procedure may be successful in the presence of an infected kidney. Aberrant vessels (unless large) may be safely divided. In 29 cases, anomalous vessels were sectioned without demonstrable ill effect. If the obstruction is outside the ureter and is the result of fibrous bands, adhesions

24. Henline, R. B.: The Cause and Treatment of Non-Calculous Uretero-Pelvic Obstructions, with Report of Sixty-Six Operated Cases, J. Urol. **34**:584 (Dec.) 1935.

and aberrant vessels, satisfactory results are obtained by complete lysis of the renal pelvis and upper part of the ureter, combined with nephropexy. The Fenger operation is not satisfactory. In the presence of strictures and high insertion of the ureter, reimplantation of the ureter into the lowest portion of the renal pelvis gave satisfactory results in 61 cases. There were 2 deaths; 2 patients required secondary nephrectomy, and 1 of these was improved. Although the function of the kidney has improved and the size of the pelvis decreased, neither has returned to normal in this series of cases.

Anomalies.—Randall and Campbell [25] reported 2 cases in which an obstructive nephropathy with pyonephrosis was caused by the passage of the ureter completely around the vena cava in its descent to the bony pelvis. Three cases in which this anomaly was found at necropsy and a case in which it was found at operation have been reported in the literature. The anomalous embryologic development responsible for this condition is described. A new and highly suggestive clinical sign, which should aid in the preoperative diagnosis of this condition, is the peculiar position that the ureteral catheter occupies in relation to the vertebral column when lateral roentgenograms are taken. In the normal position the ureter is seen to fall away from the spinal column, but when it passes behind the vena cava it is observed to be impinged against the lower lumbar vertebrae.

Ureterocele.—Moukharinsky [26] submitted a report on the pathogenesis of ureterocele, based on the study of 8 cases observed personally and a review of the literature. Three examples cited demonstrate satisfactorily that ureterocele, even though bilateral, may not be congenital but acquired as the result of traumatism or inflammation. In none of the cases reported were there any anomalies of formation. According to some authors, ureterocele is found chiefly in persons of asthenic type, with nephroptosis and visceroptosis. The asthenic constitution was present in 1 of the patients and nephroptosis in 4. In 1 patient the ureterocele was bilateral; nephroptosis of the right kidney and a kink of the upper portion of the ureter also were present on the same side. In another patient there was a ureterocele on the left side, with prolapse of the mucosa of the right ureter, while on the right side there was nephroptosis without any anomaly of the direction of the ureter. The interest here lies in the combination of a ureterocele on one side, on which the kidney was in place, and prolapse of the mucosa on the other side, on which the nephroptosis was found.

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25. Randall, Alexander, and Campbell, E. W.: Anomalous Relationship of the Right Ureter to the Vena Cava, J. Urol. **34**:565 (Dec.) 1935.

26. Moukharinsky, A.: De l'urétérocèle, J. d'urol. **38**:1 (July) 1934.

After contraction of the ureteral orifice, many authors assume that a secondary condition is necessary to provoke a ureterocele, and a great many theories have arisen; their multiplicity, however, is sufficient proof of their insufficiency. Among other erroneous statements is the assertion that the ureter, in its upper portion above the ureterocele, is necessarily subjected to dilation. Ureterograms in a number of cases in which there was no dilation have shown that the ureter was of normal size following electrocoagulation. After electrocoagulation, incision or even resection of the part of the ureter that has descended toward the urethra, the ureterocele disappears; sometimes it remains as a pad of mucosa, and the ureter and the surrounding walls resume their faculty of contraction. As for the lower portion of the ureterocele, the dilation may remain after coagulation, according to the persistence or disappearance of changes occurring in its walls. Thus, in the case of a ureterocele of large size which contained 8 calculi examination a year and a half after coagulation and evacuation of the calculi revealed dilation of the vesical end of the ureter of such extent that an attempt at catheterization failed, the catheter coiling into a ring within the persistent sac.

If one holds to the theory that weakness of the walls of the bladder or of the general system is a necessary condition for the formation of a ureterocele, one will find it impossible to explain the return to normal of the lower end of the ureter with reference to the surrounding walls of the bladder in cases in which this occurs.

The theory accepted by the author with reference to the mode of formation of a ureterocele is that of Federoff: Whether congenital or acquired, the ureterocele presents as its most marked characteristic the contraction or nonpatency of the ureteral orifice. As the result of this contraction the upper portions of the ureter are dilated by the urine; the ureter then becomes cystic and begins to swell within the bladder. As the dilation and the swelling gradually increase the end of the ureter may descend (in females) even through the urethra and come out into view. A swelling of such a kind will, of and by itself, form an obstacle to evacuation of the urine from the kidneys and will lead to dilation and atony of the ureter throughout its entire course and to dilation of the renal pelvis.

As regards treatment, there is not much controversy except in the case in which the cyst is so large as to fill the bladder or the case in which it descends through the urethra. In the former case, some authors recommend only endovesical coagulation or, if that is impracticable, coagulation within the sectioned bladder. Others differentiate between cysts with thin, transparent walls and those with thick walls, and advise the surgical treatment for the latter. Most authors approve of resection of the strangulated portion if the ureterocele has prolapsed to the

exterior. But some, for example Gottlieb, would use coagulation in all cases on the ground that resection leaves a gaping orifice behind, creating conditions favorable to reflux and to ascending infection. This is a point which Moukharinsky regards as rather well founded, especially in view of the fact that coagulation leaves undisturbed the ganglions innervating the lower parts of the ureter, the conservation of which is of great importance for maintaining the equilibrium of the muscular work which the bladder has to perform. But there is only one answer to the question whether every ureterocele ought to receive treatment: The condition is a pathologic one which, if left to itself, is likely to become the source of grave disturbances higher up in the urinary tract. The frequency of ureterocele is much greater than a review of the literature indicates, as the subject does not seem to have received the attention it deserves in the archives of clinics.

Dilatation.—Thomas and Barton [27] stated that congenital anomalies of the genito-urinary tract occur frequently in infants and children and predispose to pathologic conditions of this system. Since the advent of excretion urography and the more frequent examination of children by the urologist, the number of congenital anomalies which have been reported has increased. The incidence of congenital bilateral idiopathic dilatation of the ureters in children is greater than the present reports indicate. If such dilatation is bilateral it is a serious condition which is not improved by plastic surgery. If it is unilateral, nephro-ureterectomy offers a satisfactory result.

BLADDER

Tumors.—Smith [28] offered an analysis of a series of 150 cases of tumor of the bladder, which were observed personally. The data on 100 of these cases were fairly complete, including the end-results; the information on the remaining 50 was insufficient to permit a complete study. The cases occurred in 94 men and 56 women. The ages of the patients ranged from 29 to 84 years. The incidence among females (37.3 per cent) was relatively high compared with that in the large series reported by the Carcinoma Registry (23.75 per cent). The average age of the patients who had the papillary variety of tumor was 52.8 years; 41 per cent of them were less than 50 years of age. The average age of those who had the infiltrating type was 61.2 years; only 15 per cent were less than 50 years of age. These figures indicate that

27. Thomas, G. J., and Barton, J. C.: The Rôle of Congenital Anomalies in the Production of Urologic Conditions in Children, with Special Mention of Congenital Idiopathic Dilatation of the Ureter, Tr. Am. A. Genito-Urin. Surgeons **28**:231 (June) 1935.

28. Smith, G. G.: The Treatment of Bladder Tumors, Pennsylvania M. J. **38**:569 (May) 1935.

the average age of patients who have tumor of a high grade of malignancy is greater than that of patients who have tumor of a low grade of malignancy.

There were 41 cases of the papillary variety of tumor and 59 of the infiltrating variety.

There were 27 cases of single papillary tumor and 14 of multiple papillary tumor. In 3 cases of single tumor the diagnosis was simple papilloma, and in 6, papillary or epidermoid carcinoma; 18 cases were without pathologic diagnosis. Of the 27 patients with single tumor, a number of whom probably had papillary carcinoma, 6 had the growth removed through the open bladder. One of these, in whom epidermoid carcinoma arose from the orifice of the bladder, had twelve gold radon seeds, each containing 2 millicuries of radon, implanted. Of the other 5 patients, 1 died of carcinoma of the bladder in nine months; 4 are living three, six, eight, and nine years, respectively, after operation. Three of the latter have had no recurrence, and the fourth has not been examined.

Twenty-one patients who had single papillary tumor were treated cystoscopically by electrocoagulation; in 3 of them, one or two gold radon seeds were implanted in the wall of the bladder at the base of the tumor. These 3 patients are living and without recurrence seven months, ten months and two years, respectively, after treatment. Eighteen patients were treated by cystoscopic electrocoagulation alone; 4 of these patients are dead, and 14 are living. Of the 14 patients now living, 7 have been free from recurrence for from two to twelve years. Seven have had recurrences, chiefly in the first two or three years after destruction of the original growth, but are still alive. Six of these are now free from the growth, but small velvety patches are developing in the bladder of the other patient faster than they can be destroyed. One patient had a recurrence after eleven years; another, after seven years.

Multiple papillary tumor occurred in 14 patients; in 4 the growth was diagnosed as papilloma, in 5 as papillary carcinoma and in 1 as squamous cell carcinoma; in 4 the tumor was not diagnosed. Eleven were treated through the open bladder, 3 by coagulation and radium and 8 by electrocoagulation alone. Of the 3 patients treated with radium, 1 died in two years of carcinoma of the bladder, 1 has lived six years without recurrence, and 1, ten years with but one recurrence, six months after operation. Of the 8 patients treated by electrocoagulation alone, 1 died of carcinoma of the bladder twenty months later, and 1 died of the same disease two years after the treatment. Two have lived four and five years, respectively, without recurrence; 3 have lived three, four and seven years, respectively, with recurrence in the first two years.

The end-result bears no demonstrable relation to the presence or absence of malignancy in the tumor. The prognosis for multiple tumor is definitely worse than that for single tumor. Deaths from carcinoma in the group of patients with single tumor were 8 per cent as contrasted with 21 per cent in the group with multiple tumor. Obstinately recurring tumor was encountered in only 1 patient in each group.

Two of the 59 patients who had infiltrating tumor were treated by implantation of radium seeds through the cystoscope. In both the tumor was ulcerated, sessile and single. In one, the growth appeared to be controlled eight months after treatment, and in the other, fifteen months after treatment. Twenty-eight patients were treated by implantation of radium through the open bladder. Five patients, who appear to have been cured, have lived without recurrence for from three to fifteen years, respectively. Cystotomy and electrocoagulation were performed in 4 patients. Three of these are dead. One lived two months and died of pyelonephritis. Two died of carcinoma of the bladder within six months and three years, respectively, after operation. The fourth is living five years after operation, but the growth has evidently extended beyond the bladder into the pelvic tissues. Resection of the wall of the bladder was done in 13 patients. Seven of these have died, 3 postoperatively. Four died of carcinoma six months, nine months, two and a half years, and three and a half years, respectively, after operation. Six patients have lived for five months, one year, five years, five years, eight years and ten years, respectively, after operation.

Total cystectomy was done in 10 patients. In 6 of these the ureters were implanted in the bowel; in 3 they were implanted in the skin. Bilateral nephrostomy was done in 1 patient. Three of these patients are living and apparently well two, eighteen and seven months, respectively, after cystectomy and ureterostomy, and one, eight months after cystectomy and uretero-enterostomy. In 5 others diversion of the urinary stream was done; in 3 of these it was only a palliative measure. Two patients were subjected to ureterostomy; each lived five months. Three were subjected to uretero-enterostomy; they lived only five days, two weeks and six weeks, respectively. In the entire group of 59 patients with infiltrating carcinoma, 6 died as a result of local recurrence who might have been saved by cystectomy. All of these patients were treated by cystotomy and implantation of radium.

Rabson [29] reported 2 cases of atypical carcinoma of the urinary bladder simulating myosarcoma. In a review of the literature it was found that sarcoma of the bladder is approximately three times as common among men as among women. The incidence, according to age,

29. Rabson, S. M.: Atypical Carcinoma of the Urinary Bladder Simulating Myosarcoma: Report of Two Cases and Review of the Literature, J. Urol. **34**:638 (Dec.) 1935.

although irregular, is almost the same for both sexes. After the first ten years of life, the incidence is low.

The problem of etiology in the study of the neoplasms has been discussed by Rabson. In cases of sarcoma of the bladder occurring early in life, 8 in infants less than 1 year of age, the tumor unquestionably was embryogenetic. Cases of sarcoma have been reported in workers in the aniline industries. Experimental work has been done with the coal tar products. Bauer treated fistulous bladders in animals with these chemicals, and Perlman and Staehle injected coal tar products subcutaneously, but all reported the production of only benign fibroepithelioma. Bilharziasis was seen with sarcoma and with carcinoma by Ferguson. Kartulis also recorded the association of sarcoma with bilharziasis. Chronic inflammation may result in the appearance of lymphoid tissue in the wall of the bladder even though normally none is present.

The symptoms of sarcoma of the bladder are similar to those of carcinoma of the same organ, both in variety and degree of severity. Dysuria, hematuria and retention of urine are prominent. The site of the tumor is usually on the lateral or posterior wall or on the base, including the vesical neck. The superior and anterior walls are involved about half as often as the portions just mentioned. Multiple occurrence, considered the result of metastasis or of direct spread, has been reported observed in 32 patients, whereas a single mass has been recorded in 145.

The neoplastic masses may or may not be pedunculate. There was ulceration of the tumor in 56 instances, and in 16 there was not any ulceration. In 20 patients only was the presence of calculi observed. In 1 of these patients there had been an operation for stone twelve years before. There is a definite statement of the absence of calculi in 14 patients. The entire thickness of the wall of the bladder was invaded by the sarcoma in 45 cases, and in 16 there was not complete invasion. Operations, usually partial resection of the bladder, were done in many of the patients, but generally death occurred less than a year and frequently a half year later. Metastases were usually found in regional lymph nodes, although neoplastic masses were also seen in distant lymph nodes. All organs, with the exception of the brain, have been recorded as being the site of metastatic growth.

Cystectomy.—Freiberg [30] presented a new method for total urethrocystectomy in the female, which may be the treatment of choice in certain cases of carcinoma of the bladder:

> Preliminary lumbar ureterostomy is performed on one ureter and then, usually from one to three weeks later, on the other; the bladder is removed at a third

30. Freiberg, H. B.: Total Urethro-Cystectomy in the Female—A New Technique, J. Urol. **34**:615 (Dec.) 1935.

operation. The patient is placed in the position for lithotomy, after which the vagina is prepared in the routine manner. An incision is made in the anterior wall of the vagina, corresponding to the primary incision of an operation for cystocele. A line of cleavage is started by blunt dissection between the posterior surface of the bladder and the anterior surface of the uterus. With a gauze-covered finger, this dissection is continued backward until the bladder is completely freed from the uterus. The blunt dissection is continued laterally until the inferior surfaces of the lateral vesical ligaments are reached. The primary incision in the wall of the vagina is then carried forward and upward around the external urinary meatus. The urethra is dissected free from its bed, and the dissection is carried anteriorly beneath the pubis until the inferior surface of the pubovesical ligament is reached. With the patient in the same position except for lowering the head of the operating table, a suprapubic incision is made in the median line. The preperitoneal fat and peritoneum are freed from the inner surface of the abdominal wall by blunt dissection. The blunt dissection is continued downward beneath the pubes to the pubovesical ligament. This dissection is simply accomplished since the bladder is empty. The bladder is allowed to remain empty during the entire operative procedure. The pubovesical ligament is then ruptured, thus making the dissection from above continuous with that from below. This dissection is continued laterally for a short distance until the lateral vesical ligaments are reached. The urethra is grasped through the suprapubic wound and pulled anteriorly and upward.

Following this the lateral vesical ligaments, containing the superior and inferior vesical arteries, are isolated. A curved clamp is applied to each lateral vesical ligament, and the ligaments are severed. The urethra and bladder are then dislocated anteriorly as much as the latter is attached only to the peritoneum. The blunt dissection previously started per vagina is continued upward, completely freeing the bladder from the peritoneum and allowing for its removal. After the removal of the bladder the vesical ligaments are ligated with sutures of no. 3 chromic catgut. Two Penrose drains are introduced into the space of Retzius and allowed to extend through the incision in the vagina. The suprapubic wound is closed without drainage. The incision in the vagina is closed around the Penrose drains.

Tuberculosis.—Valerio,[31] using as a basis for discussion 2 widely different illustrative cases of primary tuberculosis of the bladder, demonstrated that a great many of the sweeping generalizations made in the literature with reference to this disease are unsound and that every case is more or less individual.

Thus, one of the patients had a hereditary predisposition to tuberculosis, while the other patient had not; one stated that he had no venereal history, while the other stated that he had had a gonorrheal infection six years previously, which allegedly had been cured. Tuberculosis of the bladder is regarded as a disease of early adult life and of youth; the first patient belonged to this age group, but the second was a man of 58 years. Nearly always the bladder is inoculated following tuberculosis of one or both kidneys, and the beginning of the

31. Valerio, Americo: Sur la tuberculose vésicale primitive, J. d'urol. **38**:530 (Dec.) 1934.

tuberculous lesions of the bladder around the ureteral orifices is considered proof of this. Clinically, there are many exceptions, and among such are the cases under consideration; in neither of these cases was the vesical tuberculosis accompanied by a corresponding tuberculosis in the kidneys.

It should be recalled that it is possible for the bacillus of tuberculosis to localize primarily in the bladder just as in the lungs, ganglions, meninges or peritoneum. When it does, one may speak of urovesical tuberculosis, which proceeds from granulations to caseation and ulceration. But if the bladder is involved following lesions of nearby organs, especially of the kidneys, the involvement may be secondary tuberculous infection of the bladder and the condition should be called "tuberculous urocystitis."

Secondary infections are of great importance from the standpoint of diagnosis, prognosis and treatment since they aggravate primary tuberculosis of the bladder and sometimes render it incurable. In the patients mentioned, who had been treated for years for "pyelonephritis," the tuberculosis of the bladder was primary. Primary tuberculosis of the bladder is of extremely slow evolution, while tuberculous cystitis is of much more rapid development and is more progressive. It is worthy of note that the first patient had complained of urinary disturbances for eight years, and the second had had a similar disturbance for thirty years. Both patients were cured, and the cure has persisted.

The lesions generally begin at the trigon or in the ureterovesical region; but in these 2 patients the ulcers were localized at the cupola and in the left lateral half of the bladder. In one patient the trigon was normal; in the other it was the site of slight grayish granulations; an abscess was forming in one of these. In both patients the ureteral orifices were easily catheterized and were intact.

The most interesting feature in these 2 cases was the fact that for many years the tuberculosis of the bladder had disguised itself as a vesical pyelonephritis, without signs of cystitis; a variety of bacteria had been found in the urine, but the bacillus of tuberculosis had not been recovered. Both patients had presented the enterorenal syndrome; one had harbored Escherichia coli in his urine, and the other had harbored enterococci. It is usual for the renal phase to come as the final stage of this syndrome, with or without simultaneous repercussions in the bladder. But in these two patients there was no cystitis; the symptoms were solely those of pyelonephritis. There was no great reduction in the functional capacity of the kidneys, and pyelography revealed nothing abnormal. While the urine did not contain the bacillus of tuberculosis it contained Staphylococcus albus, Staphylococcus aureus, streptococci and Micrococcus catarrhalis. The tendency of ulcerations to heal spontaneously was not observed here inasmuch as the disease

had been of long duration in both cases. Raising the question whether the bacillus of tuberculosis is found in the product of ulcers and in the vesical and renal urine, the author points out the inconsistency of the findings; Colson, for instance, found this organism in the urine of 84 of 88 patients suspected of having the disease, while it was not present in the urine of either of the 2 patients reported on here. The results of the inoculation of guinea-pigs were positive, and cystoscopic examination had already established the diagnosis of vesical tuberculosis.

After this study, one thing is certain, namely, that the conception of renovesical tuberculosis merits a drastic revision from the ground up, in order to get away from worn out aphorisms.

Resection.—Harris [32] described the operation of posterior segmental block excision of the neck of the bladder with primary closure, which he considers an improvement over such well recognized operations as cuneiform resection and complete extirpation of the neck of the bladder. After cuneiform resection there is likely to be recurrence of the obstruction. Extirpation of the neck of the bladder has the disadvantages of being unnecessarily extensive and leaving an open raw surface, the bleeding from which is controlled by gauze packing. The operation described by Harris has been performed on 33 patients within the past six years without mortality and, up to the present, without recurrence of obstruction. It is designed for the relief of certain obstructive conditions of the neck of the bladder when there is no gross enlargement of the prostate gland. These conditions include the various types of median bar, or disease of the posterior commissure, and general fibrosis of the prostate. The operation should not be used in the treatment of enlargement of the lateral lobe of the prostate gland, although it will occasionally prove of value if the bladder has to be opened for the treatment of recurrence of obstruction after prostatectomy. In making the selection of the type of operation to be used in relieving obstruction of the neck of the bladder, due regard must be given not only to the actual obstructive condition but also to the possible presence of complications such as calculus or diverticulum of the bladder and gross hypertrophy of the interureteric bar.

Following exposure of the base of the bladder, the tip of the right forefinger should be gradually but firmly inserted through the internal meatus, which frequently in this condition may not yield to any but the firmest and most persistent pressure. Two deep traction sutures are then placed, one on each side, about half way around the dilated rim of the prostate gland. Following this, at least 2 cm. of the hindmost sector is excised; this is done by making two deep parallel vertical incisions, one on each side of the midline, and reaching down to the level of the floor of the prostatic urethra. The intervening lip is then firmly drawn up by

32. Harris, S. H.: Posterior Segmental Block-Excision of the Bladder Neck with Primary Closure, Brit. J. Surg. **23**:45 (July) 1935.

traction forceps and cut out deeply and cleanly in a transverse direction. The bared base must be carefully examined and, if necessary, trimmed. It is important that no gross fibrous or adenomatous remnants remain. The cross-cut ends of the rim of the prostate gland are next freely undercut on each side to permit their complete retraction. Two deep hemostatic sutures are then passed on each side behind the two traction sutures that were inserted prior to the excision. The hemostatic sutures also serve to turn in, on each side, the bared face of the cross-cut ends, thus eliminating the raw surface. When hemostasis by means of these sutures has been accomplished, "retrigonization" is carried out. "Retrigonization" is the name which Harris has applied to the method of sewing down the apex of the trigon into the prostatic urethra in order to insure freedom from formation of a postoperative ledge after prostatectomy. For this step the point of the needle penetrates the base of the bladder at the deepest part behind the interureteric bar. A no. 22 French rubber catheter is passed through the urethra into the bladder, and its end, including the eye, is cut off after an opening has been made about an inch behind the eye of the catheter. The catheter is suspended in position by a silkworm suture thread. The bladder and the abdominal wounds are completely closed and the silkworm suture is suspended to a small glass rod on the abdomen.

Incontinence.—Douglass [33] said that many methods for the treatment of urinary incontinence associated with relaxation of the neck of the bladder have been employed with varying degrees of success. The Kelly method has been the most satisfactory procedure for this type of incontinence and is usually sufficient to produce a cure in the average case of relaxation of the vesical neck. Only small superficial bites may be taken in placing the mattress sutures employed in the Kelly technic; unless extreme care is employed, there is danger of penetrating the mucosa of the bladder, with the danger of the development of a fistula. Douglass suggested a plan whereby the tissues surrounding the neck of the bladder may be thickened sufficiently to permit the plicate sutures to be placed boldly and deeply in order to imbricate more tissue. This is to be effected by the use of superimposed purse-string sutures to reduce the wall of the bladder in the presence of large attenuated cystoceles. The prime purpose of this procedure, however, is to insert a valvelike bunching of tissue at the lower margin of the neck of the bladder. Two superimposed purse-string sutures, approximately 2 cm. in diameter, are placed just anterior to the vesical neck, which is outlined by exerting traction on a de Pezzer catheter placed in the urethra. The first of these sutures is invaginated and tied, and a second purse-string suture is then placed immediately over the first one and likewise invaginated. This narrows the bladder from side to side considerably. Two Kelly's mattress sutures are placed immediately over the superimposed purse-string sutures. Before the mattress sutures

33. Douglass, Marion: Loss of Urinary Control Associated with Relaxation of the Vesical Neck: A Modified Technique for Its Treatment, Surg., Gynec. & Obst. **61**:534 (Oct.) 1935.

are tied the de Pezzer catheter is carefully stretched over a stylet and withdrawn. The result of the use of this method was satisfactory.

Nerve Control.—Dees and Langworthy,[34] in an experimental study of disturbances of the bladder, cut bilaterally the second, third and fourth posterior sacral roots in 39 female cats. Normal urination no longer occurred, and the bladder showed progressive enlargement until overflow incontinence developed between the fourth and sixth postoperative days. The average capacity of the bladder at this time was 191.7 cc., or four and five-tenths times the average normal capacity. The most marked enlargement was to ten times the original capacity. Urine thereafter never escaped from the bladder except by overflow, and there was no subsequent diminution in the capacity of the organ. The bladder became readily infected, and with the most extensive enlargements hematuria occurred from rupture of capillaries in the vesical mucosa. Attempts to establish automatic micturition by passive emptying of the enlarged bladder or by emptying of the bladder before enlargement occurred were unsuccessful. When vesical pressures were recorded no waves of contraction of the pubovesical muscles occurred. There was increased resistance to passive emptying of the bladder. There was no apparent pain or discomfort attributable to vesical distention. Obstipation was marked; the cats became toxic, and the average period of survival after operation was sixteen and six-tenths days.

The abdominal sympathetic chains and hypogastric nerves were removed from 10 animals after the bladder had enlarged following section of posterior sacral roots. Five of these animals died soon after operation. In the 5 surviving animals the bladders eventually emptied automatically and efficiently. Waves of contraction of the bladder appeared when pressures were recorded; the pressure at which the vesical sphincter relaxed became lowered, and the urine, if infected, became clear. One cat survived for five months; the others, for an average of thirty-four days.

Fistula.—Lahey [35] presented a method of performing extraperitoneal implantation of ureters in the sigmoid and colon. Although it is applicable only in a limited number of cases, it is so safe and simple that it may prove useful to other surgeons.

An incision of the right rectus is made, and the parietal peritoneum is wiped back as for a ureterotomy. The ureter is then freed and cut close to the bladder; the upper end is now ready for implantation. A small opening in the parietal peritoneum, about 5 cm. in length, is made. The redundant sigmoid is pulled into

34. Dees, J. E., and Langworthy, O. R.: An Experimental Study of Bladder Disturbances Analogous to Those of Tabes Dorsalis, J. Urol. **34**:359 (Nov.) 1935.

35. Lahey, F. H., in discussion on papers by A. G. Brenizer, W. E. Lower, H. W. Cave and G. R. Livermore, Am. J. Surg. **28**:268 (May) 1935.

the peritoneal opening. Only a portion of the wall of the intestine is pulled into the opening, and the lumen is not obstructed. This portion is sutured into the opening and is thereby made completely extraperitoneal. A Coffey no. 2 transplantation may then be done. If a leak occurs, it can be only extraperitoneal. This operation should not be performed on a woman who may become pregnant, as in pregnancy complications may result from the displacement of the ureter and the fixation of the sigmoid.

(To be continued)